WATER RESOURCES DEVELOPMENT PROJECT

CONNECTICUT RIVER BASIN

BEAVER BROOK LAKE

KEENE, NEW HAMPSHIRE

DESIGN MEMORANDUM NO.1

HYDROLOGY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

MARCH 1972

8

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02154

IN REPLY REFER TO:
NEDED-W

7 March 1972

SUBJECT: Design Memorandum No. 1 - Hydrology, Beaver Brook Lake, Ashuelot River, New Hampshire

HQDA (DAEN-CWE-Y)
WASH DC 20314

In accordance with ER 1110-2-1150, there is submitted herewith for review and approval Design Memorandum No. 1, Hydrology for Beaver Brook Lake, located on Beaver Brook, Ashuelot River watershed, Connecticut River basin, New Hampshire.

FOR THE DIVISION ENGINEER:

1 Incl
as (7 cys)

JOHN WM. LESLIE
Chief, Engineering Division

WATER RESOURCES DEVELOPMENT PROJECT
CONNECTICUT RIVER BASIN
BEAVER BROOK LAKE
BEAVER BROOK, ASHUELOT RIVER
KEENE, NEW HAMPSHIRE

DESIGN MEMORANDA INDEX

No.	Title	Scheduled Submission	Submission	Approved
1	Hydrology	Jan 72	March 72	
2	General Design, Site Geology, Embankments & Foundations & Relocations	March 72		
3	Concrete Materials (Resubmittal)	Feb 72		
4	Real Estate	May 72		
6	Detailed Design of Structures	July 72		
7	Hydraulic Analysis	June 72		

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WATER RESOURCES DEVELOPMENT PROJECT
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DESIGN MEMORANDUM NO. 1
HYDROLOGY

1. GENERAL

This memorandum presents the hydrology pertinent to the design of the Beaver Brook Lake project, a small multipurpose lake and reservoir in the town of Keene in the southwestern part of the state of New Hampshire. The dam and lake will be located on Beaver Brook, a tributary of the Ashuelot River, which in turn discharges to the Connecticut River. This memorandum includes sections on climatology, streamflow, floods, droughts and the derivation of hydrologic design criteria.

2. AUTHORIZATION

The Beaver Brook Lake project was authorized by the Flood Control Act, approved 13 August 1968, Public Law 90-483, Senate Document No. 68, 90th Congress, 2nd Session. The dam and lake, with a drainage area of 6.0 square miles, was authorized as a multipurpose project with 3,000 acre-feet of storage for recreation and 2,750 acre-feet for flood control, equivalent to 8.6 inches of runoff. In the future when the city of Keene needs added supply, the recreation pool is to be converted to a water supply reservoir. Project formulation studies leading to authorization were discussed in Interim Report on Review of Survey, "Beaver Brook Dam and Reservoir," July 1965, revised December 1966.

As a result of current studies, changes in storage allocations are now recommended to include 110 acre-feet of dead storage and 730 acre-feet of seasonal joint use storage for flood control and downstream releases. Storage allocation is discussed in more detail in paragraph 13, "Storage Allocation."

3. BASIN DESCRIPTION

a. Ashuelot River. The Ashuelot River lies in the southwest corner of New Hampshire, where it drains an area of 421 square miles at its confluence with the Connecticut River near Hinsdale. Generally, the watershed is hilly with low mountains in the headwaters. A few natural lakes and ponds are also found in the area. The Ashuelot watershed is shown on plate 1-1. The river has a total fall of 1,475 feet in its length of 64 miles, but much of this drop is concentrated near the headwaters. Ashuelot River profiles are shown on plate 1-3.

b. Main tributaries. The two main tributaries of the Ashuelot River are the Branch and the South Branch. The Branch, entering the Ashuelot River just below Keene, New Hampshire, about 26.5 miles upstream from the mouth, is formed by the confluence of Minnewawa Brook and Otter Brook. The South Branch joins the Ashuelot River just above Swanzey Station, or about 23.5 miles upstream from the mouth.

c. Keene flood plain. The portion of the Ashuelot River between the Faulkner and Colony Company Dam in Keene and the Dickinson Dam in West Swanzey is referred to as the Keene flood plain. This reach is the principle flood damage area in the Ashuelot basin. The meandering river channel in the flood plain has low discharge capacity due to its small cross-sectional area and flat gradients, with the result that flood waters cause considerable depth of pondage. About 75 percent of the Ashuelot River drainage area empties into this reach of the river. Table 1 lists the approximate drainage areas of the streams that discharge into the flood plain.

TABLE 1

KEENE, NEW HAMPSHIRE FLOOD PLAIN - DRAINAGE AREAS

Location	Drainage Area in Square Miles	
Ashuelot River at the Branch		114
The Branch at mouth		100
Otter Brook at the Branch	55	
Minnewawa Brook at the Branch	33	
Local	2	
Beaver Brook at the Branch	10	
South Branch Ashuelot at mouth		72
Ash Swamp Brook at mouth		18
Local Drainage - Keene to West Swanzey		8
TOTAL at West Swanzey		312

d. Beaver Brook. Beaver Brook, with a drainage area of 10 square miles, flows southward through the city of Keene and joins the Branch near its mouth in the flood plain. The watershed is rectangular in shape with a length of about 7 miles and a width of about 1.5 miles. It has basically a single stream pattern with short side tributaries and steep slopes. This is evident from the drainage area and stream profile shown on plate 1-4. Although Beaver Brook has a total fall of over 700 feet in about 8 miles of length, the lower 2 miles in the city of Keene and that portion in the vicinity of the proposed dam are relatively flat.

From the dam site, located at river mile 4.1, the river falls rapidly for the next two miles and the channel contains considerable discharge capacity. However, once the brook reaches the outer limits of the populated areas, the streambed flattens out and it enters into a flood plain which has a width that varies from 500 to 2,000 feet. The channel depth throughout the remaining two-mile length to the mouth is approximately 5 feet. The channel capacity through this reach is estimated to be 120 cfs (about 15 csm). Discharges in excess of this result in overbank flooding with ponding developing over a large area.

4. EXISTING FLOOD CONTROL PROJECTS IN THE ASHUELOT RIVER WATERSHED

a. Surry Mountain Lake. This dam, which was completed in 1942, is located in the town of Surry on the Ashuelot River about 6 miles upstream of the Faulkner and Colony Dam. It controls a drainage area of 100 square miles, with the reservoir containing a flood control storage equivalent to 5.9 inches of runoff.

b. Otter Brook Lake. The dam, which was completed in 1958, is in the city of Keene on Otter Brook about 5 miles upstream of the confluence of the Branch and the Ashuelot River. It controls a drainage area of 47 square miles with the reservoir containing a flood control storage equivalent to 7.0 inches of runoff.

5. CLIMATOLOGY

a. General. The Beaver Brook watershed is in an area having a variable climate characterized by frequent but generally short periods of heavy precipitation. Some of these are produced by local thunderstorms and others by larger weather systems of tropical and extratropical origin moving up the eastern coast. The watershed also lies in the path of the prevailing westerlies which traverse the country in an easterly or northeasterly direction producing frequent weather changes. Winters are moderately severe, with subzero temperatures rather common. The spring melting of the winter snow cover generally occurs in late March or April.

b. Temperatures. The mean annual temperature at Keene, New Hampshire is approximately 45° Fahrenheit, with the average monthly temperatures varying from about 70°F. in July to near 20°F. in January. Extremes in temperature range from highs slightly in excess of 100°F. to lows in the -30's. Table 2 summarizes mean, maximum and minimum monthly temperatures recorded at Keene, New Hampshire for 78 years of record through 1970.

c. Precipitation. The mean annual precipitation at Keene is 38.5 inches. The greatest annual precipitation recorded was 51.2 inches in 1951 and the least annual amount was 27.1 inches recorded in 1894. Table 2 summarized the precipitation recorded at Keene for 79 years of record through 1970.

d. Snowfall. The mean annual snowfall at Keene is about 63 inches. Table 2 shows mean monthly values, based on 72 years of record through 1970.

e. Snow cover. Snow surveys have been taken in the Ashuelot River watershed since December 1948. These surveys indicate that the water equivalent of the snow cover reaches its average maximum of 5.1 inches in about mid-March. Some mean, maximum and minimum water equivalents of snow cover in the Ashuelot basin for the later winter months are shown in table 3.

f. Storms. Four general storm types are experienced in the southern New Hampshire area:

(1) Extratropical continental storms which move across the watershed under the influence of the prevailing westerlies.

(2) Extratropical maritime storms which originate and move northward along the eastern coast of the United States.

(3) Storms of tropical origin, some of which reach hurricane strength.

(4) Thunderstorms produced by local convective activity or by more general frontal action.

The most severe storms in southern and central New England have been those of tropical origin which occur during the late summer and early autumn. However, storms of any type may produce flooding in low lying sections of Keene along the Ashuelot River. Serious flooding often occurs in the Keene flood plain as a result of high volume run-off from the combination of rainfall and snowmelt.

TABLE 2

CLIMATOLOGICAL DATA AT KEENE, NEW HAMPSHIRE
Elevation 500 feet, msl

	MONTHLY TEMPERATURES Degrees F. 78 Years of Record Thru 1970			MONTHLY PRECIPITATION Inches 79 Years of Record Thru 1970			MONTHLY SNOWFALL Inches 72 Years of Record Thru 1970
	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean
January	21.4	66	-32	2.86	6.50	0.76	16.3
February	22.5	65	-32	2.66	7.02	0.60	16.6
March	32.8	85	-21	3.12	7.60	0.04	11.3
April	44.5	91	1	3.14	6.65	0.35	3.2
May	55.8	95	21	3.30	7.02	0.79	-
June	64.5	98	27	3.40	7.73	0.41	-
July	69.5	104	34	3.72	11.09	1.07	-
August	67.0	102	27	3.59	8.96	1.05	-
September	59.9	101	19	3.51	10.39	0.20	-
October	49.4	90	10	2.74	7.84	0.23	0.1
November	37.5	80	-15	3.36	7.67	0.52	3.6
December	25.4	64	-29	3.10	6.70	0.51	12.2
ANNUAL	45.8	104	-32	38.50	51.2 in 1951	27.1 in 1894	63.3

TABLE 3

WATER EQUIVALENT OF SNOW COVER
ASHUELOT RIVER WATERSHED
(December 1948-April 1970)

Date	Minimum	Mean	Maximum
February 1	0.9	2.9	5.5
February 15	0.0	3.4	7.6
March 1	0.7	4.6	9.6
March 15	1.0	5.1	9.4
April 1	0.0	3.7	8.8
April 15	0.0	1.2	6.5

6. STREAMFLOW

a. General. The U.S. Geological Survey has published records of river stages and streamflows at 5 locations in the Ashuelot River watershed for various periods from 1907 through 1963 (summarized in table 4). The records are generally good to excellent except those for periods of ice effect or no gage-height record. There is no published record of streamflow on Beaver Brook. However, a temporary recording gage has been installed on Beaver Brook in the city of Keene and is located in the Woodland Cemetery about 800 feet upstream of Beaver Street. This gage, which has a drainage area of 8.25 square miles, was established as an attempt to gather data for the proposed Beaver Brook project and has been in operation periodically since October 1962.

b. Stream runoff. Inasmuch as the Beaver Brook records are available for only a few years, the runoff records for both Otter Brook and the South Branch are considered indicative of flows on Beaver Brook. Flows of Priest Brook, a small unregulated stream with a drainage area of 19.4 square miles, located in the Millers River basin about 15 miles southeast of Keene, were also considered indicative of flows on a small stream such as Beaver Brook. Priest Brook daily flows are shown graphically on plates 1-16 through 1-19. The annual runoff for 40 years of record for the Otter Brook gaging station varied from 12.63 inches to 32.93 inches, with a mean of 22.54 inches. The mean annual runoff represents about 60 percent of the mean annual precipitation. A summary of the maximum, minimum and mean monthly runoff is shown in table 5.

TABLE 4

STREAMFLOW RECORDS

Location of Gaging Station	Drainage Area (sq. mi.)	Period of Record	Discharge Mean (cfs)	Discharge Maximum (cfs)	Discharge Minimum (cfs)
Ashuelot River at Hinsdale, New Hampshire	420	Mar 1907-	657	16,600	10
South Branch Ashuelot River at Webb, New Hampshire	36.0	Oct 1920-	59.4	5,960	0.1
Otter Brook below Lake Keene, New Hampshire	47.2	May 1958	77.7	685	0.1
Otter Brook near Keene, New Hampshire*	42.3	Oct 1923- Sep 1957	71.0	6,130	1.0
Ashuelot River below Surry Mt. Lake near Keene, New Hampshire	101	Sep 1945	172	1,320	0.4
Ashuelot River at Gilsum, New Hampshire	71.1	Aug 1922-	125	5,220	1.0

* Gaging station relocated downstream of Otter Brook Lake.

TABLE 5

MONTHLY RUNOFF

ASHUELOT RIVER
Near Gilsum, N.H.
D.A. = 71.1 Sq. Mi.
1922-1969

Month	Maximum		Minimum		Average	
	cfs	Inches	cfs	Inches	cfs	Inches
January	247	4.01	14.3	0.23	102	1.65
February	252	3.70	11.8	0.17	81	1.20
March	803	13.03	29.2	0.47	200	3.24
April	833	13.08	124.0	1.95	422	6.62
May	464	7.52	52.5	0.85	186	3.01
June	251	3.94	9.6	0.15	86	1.34
July	208	3.38	4.4	0.07	39	0.64
August	140	2.27	3.2	0.05	30	0.48
September	448	7.03	2.7	0.04	42	0.66
October	204	3.30	3.7	0.06	50	0.81
November	425	6.66	6.7	0.11	105	1.83
December	307	4.98	15.7	0.25	113	1.83
Water Year	191	36.60	39.8	7.60	122	23.30

ASHUELOT RIVER BELOW SURRY MOUNTAIN LAKE
Near Keene, N.H.
D.A. = 101 Sq. Mi.
1945-1971

Month	Maximum		Minimum		Average	
	cfs	Inches	cfs	Inches	cfs	Inches
January	347	3.64	37.6	0.31	142	1.63
February	333	3.05	50.1	0.51	129	1.30
March	473	7.54	88.5	0.90	240	3.22
April	1,022	12.20	167.0	1.85	569	6.33
May	632	5.50	94.5	0.99	288	2.77
June	280	3.13	13.5	0.14	117	1.25
July	87	0.94	5.8	0.07	37	0.41
August	136	1.54	4.9	0.06	32	0.37
September	233	3.11	9.6	0.02	47	0.48
October	239	3.26	4.4	0.07	74	0.88
November	427	4.97	4.0	0.10	146	1.80
December	479	4.37	22.7	0.52	170	1.88
Water Year	279	37.92	57.3	7.96	164.1	22.3

OTTER BROOK
Near Keene, N.H.
D.A. = 42.3 Sq. Mi.
1923-1958

Month	Maximum		Minimum		Average	
	cfs	Inches	cfs	Inches	cfs	Inches
January	151	4.10	5.8	0.16	66	1.79
February	134	3.31	13.5	0.33	55	1.37
March	440	12.00	23.2	0.63	127	3.46
April	436	11.51	67.8	1.79	215	5.83
May	220	5.99	32.5	0.88	105	2.85
June	177	4.67	12.5	0.33	54	1.42
July	146	3.98	3.7	0.10	27	0.74
August	84.5	2.30	2.2	0.06	18	0.48
September	341	9.00	1.8	0.05	31	0.82
October	135	3.69	2.9	0.08	27	0.72
November	221	5.83	7.3	0.19	62	1.65
December	154	4.20	10.0	0.27	67	1.83
Water Year	110	35.33	39.4	12.63	70.96	22.79

ASHUELOT RIVER
At Hinsdale, N.H.
D.A. = 420 Sq. Mi.
1907-1969

Month	Maximum		Minimum		Average	
	cfs	Inches	cfs	Inches	cfs	Inches
January	1,266	3.55	106.0	0.29	554	1.52
February	1,372	3.41	135.0	0.33	520	1.30
March	4,392	12.11	273.0	0.75	1,178	3.30
April	3,723	10.24	693.0	1.84	1,876	5.00
May	2,175	5.77	341.0	0.91	964	2.56
June	1,390	3.86	96.9	0.25	501	1.34
July	1,182	3.24	60.8	0.17	276	0.75
August	1,032	2.84	50.5	0.14	213	0.59
September	2,394	6.36	58.5	0.11	251	0.66
October	995	2.73	49.2	0.14	278	0.77
November	2,248	5.97	55.4	0.16	542	1.46
December	1,720	4.73	113.0	0.31	600	1.64
Water Year	1,093	35.49	216	7.04	628	20.88

SOUTH BRANCH ASHUELOT RIVER AT WEBB
Near Marlboro, N.H.
D.A. = 36 Sq. Mi.
1921-1969

Month	Maximum		Minimum		Average	
	cfs	Inches	cfs	Inches	cfs	Inches
January	120	3.86	6.4	0.20	53	1.68
February	143	4.12	9.3	0.27	45	1.31
March	366	11.73	23.1	0.74	110	3.51
April	356	11.05	64.4	1.99	172	5.34
May	186	5.97	26.6	0.85	78	2.51
June	151	4.69	7.0	0.22	44	1.37
July	102	3.25	3.0	0.09	22	0.71
August	131	4.21	2.7	0.09	17	0.53
September	252	7.81	2.6	0.08	22	0.69
October	133	4.26	2.9	0.09	24	0.76
November	244	7.55	3.7	0.11	52	1.60
December	157	5.03	9.5	0.30	56	1.80
Water Year	105	39.89	17.3	6.52	57.8	21.80

OTTER BROOK BELOW OTTER BROOK LAKE
Near Keene, N.H.
D.A. = 47.2 Sq. Mi.
1958-1969

Month	Maximum		Minimum		Average	
	cfs	Inches	cfs	Inches	cfs	Inches
January	97.5	2.42	9.1	0.21	47	1.17
February	73.3	1.67	14.3	0.33	40	0.89
March	157	6.10	29.8	0.71	93	2.51
April	432	11.51	130.0	2.50	266	6.56
May	256	4.80	40.2	0.96	115	2.27
June	141	3.33	3.8	0.08	45	1.03
July	47.9	1.18	2.7	0.06	18	0.44
August	52.7	1.27	2.2	0.05	19	0.45
September	103	2.45	0.8	0.01	20	0.48
October	93.7	3.37	0.9	0.03	35	0.95
November	212	4.85	3.2	0.08	67	1.60
December	187	3.70	12.8	0.36	71	1.68
Water Year	126	36.27	23.2	6.69	59.48	20.10

7. FLOODS OF RECORD

a. General. Outstanding floods on the Ashuelot River may result from early spring storms combined with melting snow, such as the flood of March 1936, or from summer or fall storms, such as the record flood of September 1938. In addition, local thunderstorms can cause serious flash floods on the smaller streams.

b. Flood history.

(1) Ashuelot River. The Ashuelot River watershed has experienced seven major floods in recent years. Table 6 shows the peak discharges of these floods at the U.S. Geological Survey gaging stations on the Ashuelot River at Gilsum, New Hampshire, South Branch Ashuelot River at Webb, New Hampshire, and Otter Brook near Keene, New Hampshire. Also included is an estimate of peak discharges on Beaver Brook at Marlboro Street.

TABLE 6

FLOODS OF RECORD
Peak Flow (cfs)

Flood	Ashuelot R. at Gilsum, N.H. (71.1 sq. mi.)	So. Branch at Webb, N.H. (36.0 sq. mi.)	Otter Brook near Keene, N.H. (42.3 sq. mi.)	Beaver Brook at Marlboro Street (9.5 sq. mi.)
Nov 1927	2,760	3,560	3,180	-
Apr 1934	3,490	1,010	3,020	-
Mar 1936	4,400	3,880	3,580	900*
Sep 1938	5,220	5,960	6,130	2,200*
Nov 1950	3,700	2,010	3,540	500*
Oct 1959	2,700	4,350	5,000*	600
Apr 1960	2,800	2,290	2,000*	600*

*Estimated flow

The November 1927 flood resulted from rainfall of 4 to 5 inches falling on ground saturated from excessive rains during the previous month. The April 1934 flood combined heavy rains with considerable snowmelt. The flood of March 1936 is the second largest of record in the Ashuelot River watershed and resulted from two major rainstorms which, combined with heavy snowmelt, caused two major rises in river stages only six days apart. The largest flood of record occurred in September 1938 when a hurricane passed over the watershed. Rainfall accompanying this storm, combined with precipitation of the previous three days, totalled more than 10 inches with a resulting total runoff in the Ashuelot basin of 5.2 inches. The November 1950 flood was a result of 3 to 4 inches of intense rainfall on previously wet ground. The October 1959 flood, which produced substantial peaks on the Branch and South Branch rivers, was a result of about 4 inches of rain in 24 hours. The April 1960 flood occurred when 3 to 4 inches of rain fell on snow with a high water content, and as is the general case, flood stages on lower Beaver Brook were also affected by backwater from the Ashuelot River.

(2) Beaver Brook. Flooding on Beaver Brook has been a recurring problem since the earliest times. Periodically, at five to ten year intervals since 1813, the brook has flooded extensive areas from Beaver Brook mouth to Main Street. The accounts of high water in recent times since 1900 includes references to amounts of rainfall and it appears that a rainfall of more than two inches in 24 hours results in overbank flooding on the brook. Following is a chronological list of damaging floods that have recently occurred on Beaver Brook: November 1927; March 1936; September 1938; September 1944; November 1947; September 1955; October 1959 and April 1960.

c. Flood profiles. High water profiles in the lower end of Beaver Brook were determined from field data following the floods of March 1936, September 1938 and April 1960 and are shown on plate 1-5. The high water of May 1960 was approximately bank full capacity, with an estimated flow of 120 cfs.

8. ANALYSIS OF FLOODS

From previous studies for the existing flood control reservoirs, it has been determined that the lower portion of Beaver Brook is in the flood plain of the Ashuelot River. This flood plain is a large storage reach with its outflow at the dam in West Swanzey. With normal Ashuelot River flows, Beaver Brook stages are related to the discharge in Beaver Brook. With increased flow in the Ashuelot River, the storage reach begins to fill, eventually causing a backwater effect up the lower end of Beaver Brook. The Beaver Brook stages are then a combination of Ashuelot River stages and Beaver Brook discharges. As indicated by the flood profile on plate 1-5, the effect of the Ashuelot River backwater in a major flood can extend up Beaver Brook to the vicinity of Roxbury Street.

In the reaches above Roxbury Street, the elevation and gradient of the streambed are such that for all ranges of flow, the stages are a function only of Beaver Brook discharges.

9. FLOOD FREQUENCIES

For use in the economic analysis, discharge-frequency curves were developed for the Ashuelot River at West Swanzey and for Beaver Brook in accordance with procedures published in ER 1110-2-1450, "Hydrologic Frequency Estimates," dated 10 October 1962. The method considers that the logarithmic value of annual peak flows are normally distributed, thereby permitting the application of standard statistical analysis. This enables the discharge-frequency curve to be defined by its mean value and standard deviations. Statistical analysis of flood flows in New England have indicated that the data had a positive skewness.

The discharge-frequency curve for Beaver Brook was derived from correlations with gaging station records from the South Branch. The statistical analysis resulted in the September 1938 flood of record on Beaver Brook having an annual chance of occurrence of about one percent or average recurrence interval of 100 years.

Table 7 lists the natural discharge frequencies for the Ashuelot River U.S. Geological Survey gage at Hinsdale and the South Branch gage at Webb. Also listed are the derived frequencies for Beaver Brook at Marlboro Street. The adopted mean and standard deviation for Beaver Brook was 2.616 and 0.290, respectively. Surry Mountain and Otter Brook projects reduce the natural peak discharge frequencies at Hinsdale by about 40 percent. With Beaver Brook added, it will be increased to about 42 percent. Beaver Brook Lake will reduce peak flows on Beaver Brook at Marlboro Street by about 60 percent.

TABLE 7

PEAK DISCHARGE FREQUENCIES

Percent Chance Annually	Ashuelot River at Hinsdale (D.A. = 420 sq. mi.)	South Branch at Webb (D.A. = 36 sq. mi.)	Beaver Brook at Marlboro Street (D.A. = 9.5 sq. mi.)
0.50	31,000	10,400	2,800
1.00	24,000	7,200	2,200
2.00	19,000	5,000	1,800
5.00	13,800	3,200	1,300
10.00	10,600	2,200	990
20.00	8,100	1,600	715
50.00	5,700	1,100	400

10. DROUGHTS

The long term normal streamflow of approximately 22 inches, in Massachusetts, is actually the average of many highs and lows. When rainfall is below average for a period of time, the area experiences a drought, a drought in this case being defined as a period of shortage in streamflow. The recent drought of the sixties, for its duration, was the greatest ever experienced in the southeastern New England area, based on over 200 years of record. The drought of the 1960's was more severe in the interior than along the coast. The accumulated deficiencies in rainfall in central Massachusetts and southwestern New Hampshire for the period 1961-1968 were about 63 inches, which is equivalent to 1.5 years of average rainfall.

Considering Priest Brook representative of a small unregulated stream in the area, a statistical frequency analyses was made of 50 years of streamflow records using procedures described in ER 1110-2-1450, "Hydrologic Frequency Estimates." Assuming a normal logarithmic distribution in annual streamflow, frequency curves were developed from the mean and standard deviation of the logarithms of yearly runoff, assuming a skew coefficient of zero. Frequency analyses were made for both yearly and consecutive year average streamflow. The resulting frequency curves are shown on plate 1-6. The 1964 climatological year low flow, the lowest single year of record at Priest Brook, was 7.97 inches. The lowest consecutive 2-year period, 1964 and 1965, averaged 9.85 inches per year.

11. FLOW DURATIONS

Computer printouts of yearly low and high flows for varying consecutive day periods are shown on plates 1-7 and 1-8, respectively. This flow duration data was derived from records of the South Branch U.S. Geological Survey gage with a drainage area of 36 square miles. The flow duration data, as presented, is considered generally applicable to the Beaver Brook watershed on a direct drainage area relationship.

12. STORAGE CAPACITY

Area and capacity curves for the Beaver Brook reservoir were based on Corps surveys taken in 1970-71, supplemented by 1969 photogrametric survey data from the New Hampshire State Highway Department. The developed area and capacity curves are shown on plate 1-9.

13. STORAGE ALLOCATION

In the December 1966 Interim Report, reservoir storage allocation at Beaver Brook Lake consisted of 3,000 acre-feet for recreation-water supply and 2,750 acre-feet, equivalent to 8.6 inches of runoff, for flood control. Storage provisions for sedimentation and dead storage were not considered. To meet this need, it is now proposed to provide 110 acre-feet of dead storage by reducing the flood control storage to 2,600 acre-feet (8.1 inches). It is further planned that when the reservoir becomes a water supply, an additional 730 acre-feet of the authorized flood control storage will be used seasonally for both flood control and downstream releases. The regulation of the 730 acre-feet of joint use storage is discussed under paragraph 24, but basically, the seasonal storage would be filled each year during the spring freshet and used to assist the city of Keene in providing a downstream release of 1 cfs the remainder of the year (1 cfs for 365 days = 730 acre-feet). Those years in which there is insufficient runoff to refill the water supply and joint use storage, the downstream release will be reduced or forfeited so as not to encroach upon the safe yield of the water supply. Forty years of Otter Brook runoff records were analyzed and it was found that there were 4 years in which storage could not be refilled, indicating that such a plan would provide approximately a 90 percent dependable minimum downstream release of 1 cfs. The joint use storage will be operated according to a rule curve as discussed under "Reservoir Regulation" to insure that all flood control storage is available by the fall season. A tabulation of storage allocations as presently proposed is shown in table 8.

TABLE 8

BEAVER BROOK LAKE
STORAGE ALLOCATIONS

Purpose	Elevation (ft,msl)	Net Storage Acre-Feet	Net Storage Inches
Sedimentation and Dead Pool	789	110	0.34
Water Supply	789-811.5	3,000	9.4
Seasonal Use	811.5-815	730	2.3
Remaining Flood Control	815-822	1,910	6.0
TOTAL		5,750	18.0

14. SPILLWAY DESIGN FLOOD

a. General. The spillway design flood represents the most severe conditions of runoff that would result from the probable maximum precipitation falling on ground saturated by previous rains. The discharge capacity of the flood control conduit outlets is relatively small, hence it was assumed that all flow would pass over the spillway. The spillway design inflow was determined by developing a representative unit hydrograph to which was applied the probable maximum rainfall.

b. Unit hydrograph. The limited discharge records for Beaver Brook did not provide the necessary data for direct derivation of a unit hydrograph. A representative synthetic unit hydrograph was developed, using procedures in EM 1110-2-1405, for the 5.5 square mile watershed draining to the 0.5 square mile reservoir with the lake filled to spillway crest. Rainfall on the lake surface was later accounted for by adding it directly to the developed reservoir inflow hydrograph.

In the development of a unit hydrograph it was determined that the presence of the reservoir would greatly shorten the time of concentration of rainfall runoff to the lake. As a comparison, without the project the flow path to the dam site is about 4 miles in length with an average slope of 100 feet per mile. With the reservoir filled to spillway crest, the average flow path to the edge of the lake will be reduced to 2 miles with an average slope of 200 feet per mile. Travel time through the full reservoir by translation would be so short as to be insignificant. It is therefore considered that a full reservoir would shorten the time of concentration of rainfall runoff to the dam site from about 3.5 hours to an estimated 2 hours.

Using appropriate Snyder's coefficients, determined for other small drainage areas in New England, a synthetic 1-hour unit hydrograph was developed representing the combined runoff of all tributaries to the edge of the full reservoir. This unit graph was later converted to a 3-hour unit hydrograph after it was determined that spillway requirements were quite insensitive to short duration, high intensity runoff, but more a function of runoff volume due to the large amount of surcharge storage.

Following is a list of pertinent unit hydrograph data. The adopted 3-hour unit graph is shown on plate 1-10.

UNIT HYDROGRAPH PERTINENT DATA

	1-Hour Unit Hydrograph	3-Hour Unit Hydrograph
D.A.	5.5 sq. mi.	-
L	2 miles	-
Lca	1 mile	-
$(L\ Lea)^{0.3}$	1.23	-
Slope	200 ft/mile	-
Ct	1.6	-
Cp 640	370	-
Tp	2.0	2.5
qp	182	124
Q	1,000	680

c. Probable maximum precipitation. The spillway design storm is based on the probable maximum precipitation (PMP), as determined by the Hydrometeorological Section of the National Weather Service. Figure 1 of Hydromet Report 33 indicates that for zone 1, where this project is located, the PMP for a drainage area of 200 square miles is 19.5 inches in 24 hours. Appropriate factors have been used in relating this to other time periods and to the drainage area of 6 square miles in accordance with EC 1110-2-27. Resulting values are shown in the following table:

Duration (hours)	Percent of Index Rainfall	Probable Maximum Precipitation	21.5% Reduction Factors* (inches)	Spillway Design Storm (inches)
6	117	22.8	4.9	17.9
12	128	25.0	5.4	19.6
24	139	27.1	5.8	21.3

* Reduction permitted because rainfall isohyetals are unlikely to conform to shape of drainage basin

Table 9 presents rates of precipitation, losses and rainfall excess rearranged into a selected storm pattern to compute the most critical spillway design flood inflow. The most intense 6-hour rainfall was subdivided into two 3-hour amounts, with 67 percent falling in one 3-hour period and 33 percent in the other. Rainfall intensities were assumed to be uniform during these two 3-hour periods of the maximum 6-hour total and also during the other 6-hour rainfall periods. Losses from infiltration, surface detention, and transpiration were assumed at a rate of 0.2 inch per 3-hour period which is consistent with minimum losses determined in previous studies for the New England area.

d. Spillway design inflow. The spillway design flood inflow to Beaver Brook Lake was derived by applying the rainfall excess values of table 9 to the adopted unit hydrograph which was applicable to 5.5 square miles of land area. To this was added the direct rainfall on the 0.5 square mile area of the reservoir itself. The resulting inflow hydrograph had a peak of 10,411 cfs (1,735 csm) and is shown on plate 1-10.

e. Spillway design outflow. The design flood described above was routed through the surcharge storage, using the reservoir capacity curve shown on plate 1-9, and various spillway lengths. For the finally selected spillway length of 100 feet and the reservoir initially filled to spillway crest, the resulting maximum spillway discharge was 6,500 cfs with a maximum water surface elevation of 829.0 feet, msl, equivalent to 7.0 feet of surcharge. Plate 1-10 shows a graphical summary of the spillway design flood for Beaver Brook Lake. Discharge ratings for the spillway were computed using a coefficient of 3.8 in the conventional weir formula plus allowances for friction loss in the approach channel. Routings were made, assuming no discharge through the flood control outlet. It is noted that the resulting surcharge storage for the spillway design flood represents 2,550 acre-feet, equivalent to 8 inches of runoff or 40 percent of the total storm runoff.

f. Snowmelt consideration. The selected spillway design flood does not include runoff from snowmelt, but consideration was given to the possibility of such a flood in the basin. Although a spring storm, combined with snowmelt, would produce a flood having a somewhat higher volume than the all-season storm, it is logical to assume that there could be heavy snow cover on the ground, only if there had been little or no antecedent runoff. In this case, the flood control portion of the reservoir would be empty at the start of the spillway design flood. Also, rainfall on a snowpack would reduce peak runoff rates, thereby reducing peak inflow to the reservoir.

TABLE 9

PROBABLE MAXIMUM PRECIPITATION

Time (hours)	Precipitation (inches)	Losses (inches)	Rainfall Excess (inches)	Rainfall Pattern (inches)
0	0	0	0	0
3	12.0	0.2	11.8	0.2
6	5.9	0.2	5.7	0.2
9	.9	0.2	.7	.7
12	.9	0.2	.7	5.7
15	.4	0.2	.2	11.8
18	.4	0.2	.2	0.7
21	.4	0.2	.2	0.2
24	.4	0.2	.2	0.2
Total	21.3	1.6	19.7	19.7

15. TOP OF DAM ELEVATION

a. Freeboard for wave action. The procedure outlined in Engineer Circular 1110-2-27 was used to determine wave height, wave runup and wind setup. Winds producing maximum waves and setup on the slope of the Beaver Brook Lake dam would have to blow from due north. Information on maximum wind velocity and direction at Concord, New Hampshire, the nearest wind station, is shown in table 10.

This table shows that winds approaching or exceeding 50 miles per hour have been experienced. However, these values are for the fastest minute, or for gusts, and were experienced in the exposed area at Concord Airport. Appreciably lower values would be expected for the relatively sheltered location of Beaver Brook Lake and for the critical period of about 15 minutes which would be required to

TABLE 10

MAXIMUM WINDS AT
CONCORD, NEW HAMPSHIRE

Elevation 342 msl
1938 through 1970

Fastest Mile		
Speed MPH	Direction	Date
43	NW	Jan 1945
42	N	Feb 1950
71	NE	Mar 1950
52	NW	Apr 1945
48	NW	May 1945
38	SW	Jun 1957
37	NW	Jul 1944
56	E	Aug 1954
42	E	Sep 1960
39	NW	Oct 1944
72	NE	Nov 1950
52	NW	Dec 1962

Prevailing direction NW
Maximum 72 NE, November 1950

generate waves under deep water conditions with an effective fetch of 0.7 mile. Therefore, a design wind velocity of 40 mph over land was considered reasonable and was adopted. This combination of wind and fetch would generate waves 1.5 feet high for significant wave heights. Wind setup for this reservoir would be about 0.1 foot and wave runup on the riprapped slope would be about 1.7 feet for significant waves and 2.3 feet for maximum waves. As prescribed in the referenced Engineer Circular, minimum freeboard should be 3.0 feet when flood routing starts at spillway crest elevation (case 2 in paragraph c) or 5.0 feet starting at 50 percent flood control capacity (case 1), the governing criteria being that which results in the highest dam elevation. Both of these values are greater than the computed value of 1.7 feet of wave runup for significant waves.

b. Freeboard for seismic effect. For this site the freeboard for seismic effect, 3 percent of height of dam (.03 x 48 = about 1.5 feet), is less than conventional freeboard determined from a study of wave action. Accordingly, the conventional freeboard governs.

c. Selected elevation for top of dam. The tentative elevation of the top of Beaver Brook Lake was determined by the following data:

	Case 1	Case 2
Reservoir elevation at start of flood	817.0	822.0
Spillway crest elevation (msl)	822.0	822.0
Maximum head on spillway (ft)*	5.8	6.6
Head loss, reservoir to spillway (ft)	0.3	0.4
Minimum freeboard (ft)	5.0	3.0
	833.1	832.0
Adopted elevation for top of dam	833.0	

* With spillway length of 100 feet

16. ROUTE 10 HIGHWAY CROSSING

a. General. The relocated Route 10 highway will cross the Beaver Brook Valley just upstream of Beaver Brook Lake. The brook, upstream of the highway, has a drainage area of 2.6 square miles and the stream will be conveyed in a culvert through the highway embankment. It is presently planned that a 50 acre wildlife conservation pool, proposed in the Interim Report, will be maintained on the upstream side of the highway by constructing a weir at the entrance to the culvert. The weir, with a crest at elevation 828 feet, msl, will be equipped with stoplogs for minor adjustments in pool level, and a 1.5 x 1.5 feet gate for emptying the pool.

b. Culvert size. The culvert will be 4 x 5 feet in size or the equivalent. The culvert was sized for a 50 year frequency inflow with a peak of 700 cfs and a 19 hour runoff volume of 4 inches. With a 4 x 5 foot culvert, the lake, at elevation 822 and a starting conservation pool elevation at 828 feet, msl, the design 50 year flood inflow would cause the conservation pool to rise to elevation 831 feet, msl, 3.5 feet below the proposed minimum road level at 834.5 feet, msl.

c. Conservation pool capacity. Flood routings were made through the conservation pool storage using the following area capacity data.

Elevation (ft,msl)	Area (acres)	Storage (ac-ft)
826	34.4	
		90.4
828	56	
		210.2
830	63.8	
		342
832	68	
		480
834	70	

d. Highway effect on spillway design. The effects of the highway crossing in the event of a spillway design flood was analyzed in the following manner. The total spillway design flood inflow was prorated above and below the road crossing by respective drainage areas. The inflow above the crossing was routed through storage to determine the outflow to the downstream side of the crossing and this flow was then added to the downstream inflow. This modified inflow to the principle storage reservoir was then routed through surcharge storage to determine the modified spillway surcharge. In this analysis the area above the crossing filled and spilled over the roadway at elevation 834.5 feet, msl. The main pool crested at a maximum modified surcharge elevation of 828.2 feet, msl or 0.8 feet lower than in the analysis with no highway crossing.

It was further determined that if the road embankment suddenly failed at time of peak stage and instantaneously emptied the entire upstream 750 acre-feet of estimated storage into the main reservoir, the stage in the lower pool would rise 1.8 feet. This increase on top of the modified surcharge would produce a maximum stage only 1.0 foot higher than the design surcharge. It was considered that the 4 feet of freeboard was adequate for such an eventuality and no additional allowance was made for road failure in the spillway design.

17. DEPENDABLE YIELD

a. General. Yield studies for Beaver Brook Lake were made using flow records of the U.S. Geological Survey gage on the South Branch. It was assumed that flows on Beaver Brook were proportional by drainage area to those on the South Branch. Previous studies for the Interim Report involved the statistical analysis of the flow data. More recent studies involved the detailed analysis of the record 1964 through 1966 drought.

b. Dependable yield from Interim Report. The city of Keene has requested the inclusion of 3,000 acre-feet of storage for future water supply. Statistical studies for the Interim Report and studies by the city's consultant indicated that this volume of storage would provide a yield of more than 4.0 m.g.d. with a 98 percent dependability.

c. Revised dependable yield. The drought of the 1960's resulted in unusually low runoff on many streams. On both Otter Brook and South Branch, the spring runoff in 1965 was the lowest of record, and this, combined with low flow in 1964, produced a critical 20 month period, June 1964 through January 1966. Assuming Beaver Brook flows were proportional by drainage area with South Branch, a mass curve for this critical period was developed for Beaver Brook and is shown on plate 10. With 3,000 acre-feet of water in storage at the start of the critical period, a firm yield of only 3.3 m.g.d. could be maintained. Losses from evaporation and leakage would be relatively small, but considering this, plus the uncertainty of the streamflow data, it would not be ultraconservative to assume a value of 3.1 m.g.d. for dependable flow. A storage-yield curve, based on the sixties' drought, is shown on plate 1-12.

The significance of the minimum dependable flow of an individual reservoir in a system of reservoirs and ground water wells is dependent upon the ability of the remaining reservoirs and wells to provide the water demand during the critical period. Though the minimum yield of the Beaver Brook reservoir as an independent source would be about 3.1 m.g.d., its average annual yield in an integrated system would be about 5 m.g.d., assuming a downstream release rate of 1 cfs.

18. EVAPORATION

Based on U.S. Geological Survey Atlas HA-7, the average annual loss by evaporation from lakes in southern New Hampshire is 27 inches, whereas the average loss by evapotranspiration from land area is 22 inches. Thus, replacement of land area with water results in an average net loss of 5 inches per year. The maximum normal pool at Beaver Brook (bottom of flood control pool) will have an area of 200 acres. This will result in an average annual net loss due to evaporation of about 80 acre-feet.

19. FLOOD CONTROL STORAGE

Corps of Engineers flood control reservoirs in New England generally have flood storage capacities equivalent to from 6 to 8 inches of runoff from the contributing drainage area. The amount of storage selected has varied, depending on the geographic location of the reservoir, physical limitations at the site and economic considerations. In the case of Beaver Brook Lake, there were no physical limitations at the site to restrict the development of adequate storage and the authorized flood control storage was based on economics. Preauthorization studies determined that net benefits were maximized at Beaver Brook with 2,750 acre-feet (8.6 inches) of flood control storage. The results of this optimization study were graphically illustrated on plate 3 of the Interim Report for Beaver Brook, revised December 1966.

With the inclusion of 110 acre-feet of dead storage, the recommended flood control storage for Beaver Brook is now 2,640 acre-feet, equivalent to 8.3 inches of runoff. This storage is adequate to control a standard project flood and it is further concluded, based on experience in the operation of other reservoirs in New England, that the use of 730 acre-feet of storage for other uses during the less flood prone summer season will not significantly reduce the flood control effectiveness of the project.

Volume runoff-frequency curves for the Ashuelot River basin, based on flow duration analysis of South Branch records, are shown on plate 1-13.

20. RESERVOIR OUTLETS

a. General. The outlet works for Beaver Brook Lake will consist of a gated intake tower with a primary flood control outlet at the bottom. Secondary multilevel intakes will also be provided to permit selective withdrawal of domestic water supply and downstream releases. These multilevel gates will also be designed with adequate capacity for normal flood regulation.

b. Flood control outlet. The capacity of the primary outlet must be adequate to: (a) pass normal streamflow, (b) pass discharges required for regulation of the reservoir during floods, (c) permit evacuation of the flood control storage within a reasonable period of time, and (d) pass a flood of reasonable size during construction without requiring cofferdams of excessive height. A 3 x 4 foot conduit, or the equivalent, will meet the above criteria and is recommended. This conduit will have a capacity of about 300 cfs with a pool at 811.5 bottom of the flood control pool, and 370 cfs with a full pool.

c. Time of emptying. Assuming an average reservoir outflow of 335 cfs and allowing for an inflow of 20 cfs, the time required to drain the flood control pool from spillway crest under emergency conditions would be about 4 days. Time to empty the flood control pool while not exceeding safe channel capacity would be 8 to 10 days. In an emergency, the 3,000 acre-feet of water supply would be emptied in an additional 7 days.

d. Channel capacity. The channel capacity of Beaver Brook downstream of the dam was estimated during preauthorization studies to be 120 cfs. With the proposed flood control outlet, a discharge in excess of 200 cfs could be maintained with the pool at minimum flood control level.

e. Stream diversion during construction. The construction schedule may require the erection of a temporary cofferdam to divert the stream through the outlet in order to construct the foundation of the dam in the dry. The construction flood for Beaver Brook Lake was based on a 10 year frequency one-day volume runoff of 1.3 inches based on South Branch high flow durations. A triangular construction flood hydrograph with a 24 hour base and a resulting 400 cfs peak was developed and routed through the reservoir. With the proposed outlet conduit at invert 778 feet, msl, the pool would rise to elevation 790 in passing such a flood, therefore, a cofferdam with top at elevation 792 feet, msl is recommended. The cofferdam will not be of sufficient height to pose a major threat from floods greater than the construction flood. However, provisions for gradual breeching rather than sudden failure in the event of greater floods will be considered in cofferdam design.

f. Water supply outlets. In addition to the flood control outlet, secondary multilevel outlets will be provided to permit selective withdrawal of water from two different elevations. The same outlets will be used for withdrawal of both water supply and minimum downstream release. The purpose of the downstream release is for maintaining downstream environmental and aesthetic regimens, and there is no known reason why the desired water for domestic supply will not be adequate in quality for downstream release. It was concluded that a separate system for withdrawal of the 1 cfs flow could not be justified. To meet suggested OCE criteria, each multilevel outlet will be designed with a minimum capacity of 65 cfs with the pool at elevation 811.5 feet, msl. This capacity is equivalent to 10 cfs per square mile and is adequate to regulate a 5 year frequency all-season flood with storage encroachment not exceeding 320 acre-feet (1 inch runoff). Analysis was based on high flow duration data for South Branch Ashuelot River. The hydraulic design of all outlets will be presented in Design Memorandum No. 7, "Hydraulic Analysis."

21. FREQUENCY OF FILLING

Plate 1-14, a curve denoting the estimated frequency of filling of the Beaver Brook Lake flood control pool, was developed from analysis of streamflow records and the regulation experience of existing flood control reservoirs. In a multipurpose project such as Beaver Brook Lake, it is not possible to determine a precise reservoir stage frequency relation. The stage attained for any flood will be dependent on the concurrent stage of the multipurpose pool at the beginning of the flood. However, the curve shown is considered a reasonable guide for real estate acquisition.

22. GUIDE TAKING LINES

In accordance with teletype changes to ER 405-2-150, dated July 14, 1971, land acquisition will be required to the top elevation of controlled storage, plus a reasonable freeboard, or to a line 300 feet horizontally from the conservation pool, defined as the top of all planned storage not devoted exclusively to flood control, whichever is greater. The guide taking line adopted for the principle reservoir at Beaver Brook Lake will be at elevation 825 feet, msl, 3 feet above spillway crest, or 300 feet horizontally from the elevation 815 feet, msl line, whichever is greater. The guide taking line for the upstream conservation pool will be elevation 833 feet, msl, 5 feet above the normal pool level of elevation 828 feet, msl or 300 feet horizontally from the normal pool level, whichever is greater.

23. WATER QUALITY

a. General. Water quality at the Beaver Brook dam site is generally considered good, with a minimum amount of development in the watershed. The State of New Hampshire has adopted a class B water quality classification for Beaver Brook, and existing stream quality is designated as being class B upstream from the confluence with Otter Brook and class C downstream from this point. A description of classes B and C standards is contained in table 11.

TABLE 11

NEW HAMPSHIRE
WATER QUALITY STANDARDS

	CLASS B	CLASS C
	Acceptable for bathing and recreation, fish habitat and public water supply after adequate treatment. (High aesthetic value.)	Acceptable for recreational boating, fish habitat, and industrial water supply. (Third highest quality.)
Dissolved oxygen	Not less than 75% Sat.	Not less than 5 p.p.m.
Coliform Bacteria MPM/100 ml.	Not more than 240.	Not specified.
pH	5.0-8.5	5.0-8.5
Substances potentially toxic	Not in toxic concentrations of combinations.	Not in toxic concentrations or combinations.
Sludge deposits	Not in objectionable amounts.	Not in objectionable amounts.
Oil and grease	None	Not in objectionable amounts.
Color and turbidity	Not in objectionable amounts.	Not in objectionable amounts.
Slick, odors and surface floating solids	None	Not in objectionable amounts.

A preimpoundment sampling program is now in progress and will be continued this next summer season. Streams of this type in the area do experience some discoloration during periods of low flow consisting of leaching from highly organic swamps.

Further water quality analysis, including studies for proper location of the multilevel outlets will be presented in Design Memorandum No. 7, "Hydraulic Analysis." Following is a discussion of water quality considerations both downstream and within the reservoir of the planned project.

b. Downstream. Prior to use of the Beaver Brook Lake project for water supply, the lake will have little effect on downstream flow either in quantity or quality. Inflow will simply be passed through the reservoir within a reasonable amount of time. The use of multilevel intakes will permit withdrawal of cooler waters during the hottest season of the year, however, the reduction will be small and of short duration due to the shallowness of the lake and thus no downstream quality benefits are claimed.

The Beaver Brook stream, just downstream from the dam, flows through a steep reach of channel before entering the very flat reach through the flood plain. This steep turbulent reach will serve to reaerate the less than saturated cooler flows released from the deeper zones in the reservoir.

When Beaver Brook Lake is used for water supply, seasonal storage will be utilized to help provide a minimum downstream flow of 1 cfs. Beaver Brook is a small stream passing through an urban area and there is simply no significant fish and game or recreation benefits to be realized. Though the 1 cfs release will be cool, high quality water for the most part, there will be times, due to the nature of the impoundment, when the released flow will be quite high in temperature.

There exists a need for flow augmentation on the mainstem Ashuelot River for quality enhancement. However, the Beaver Brook project is too small in scope to be considered for that purpose. Other studies, in which the much larger Otter Brook Lake is being considered as a possible facility for providing low flow augmentation on the mainstem Ashuelot River, are presently underway at NED.

c. In-reservoir. The normal water supply pool at Beaver Brook Lake will have a capacity of 3,000 acre-feet, a water surface area of 200 acres and an average depth of 15 feet. As the reservoir is drawn during drought periods for water supply, all three values become proportionally less. Because of the smallness of the impoundment, both in depth and volume, the temperature and/or quality regimen within the impoundment cannot be computed with any degree of reliability with present computer modeling methods. A graphical approximation of a summer season heat budget for the lake is shown on plate 1-15. It is reasonable to believe that, due to shallowness, the reservoir will not be greatly stratified. With its large surface area and capacity in relation to inflow volume, and the resulting long detention period, it is expected that water temperatures will become quite high during the latter summer months, particularly in the dryer years. It is also reported unofficially that other similar reservoirs in the Keene water supply system have experienced periodic "taste and odor" problems. It is expected that Beaver Brook Lake may have similar characteristics. The city of Keene presently plans to install a treatment plant for the processing of all reservoir waters, including that from Beaver Brook Lake.

A study is also underway to determine the practicality of removing high organic soils from the reservoir area prior to construction. This study and conclusions will be reported in Design Memorandum No. 2, "General Design."

24. RESERVOIR REGULATION

a. General. The project will be operated:

(1) To provide downstream flood protection, primarily on Beaver Brook,

(2) To provide a permanent pool for recreational purposes, which in future years (about 1985) will be converted to a water supply reservoir for the city of Keene,

(3) To provide downstream releases in order to maintain existing environmental and aesthetic regimens in Beaver Brook.

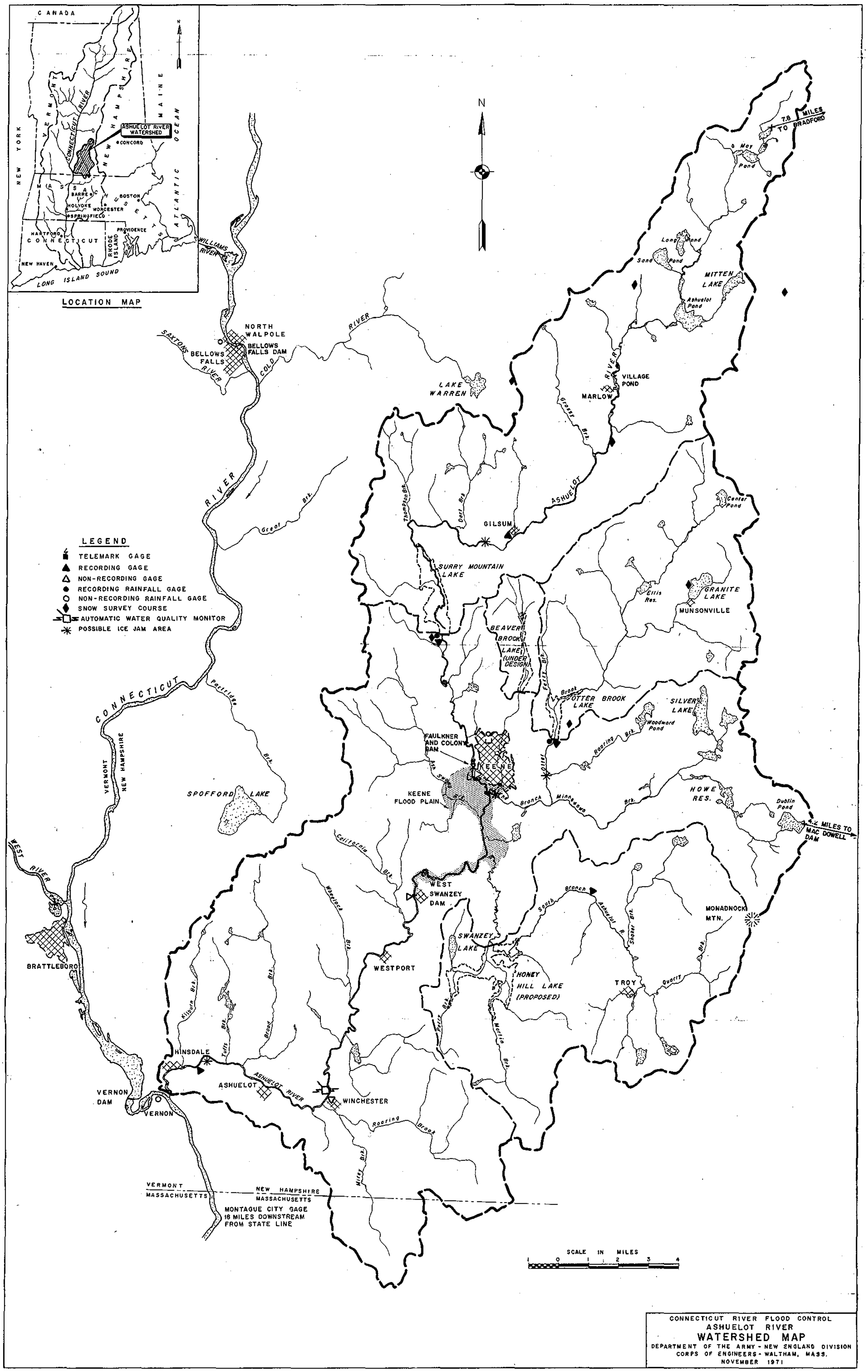
During construction of the project, the Reservoir Control Center of the Water Control Branch will establish detailed regulation procedures.

b. Flood control. Beaver Brook Lake discharges will be regulated by the Corps primarily to prevent or reduce downstream floodflows on the lower, populated 3-mile stretch of Beaver Brook as it passes through Keene. As previously mentioned, the lower portion of Beaver Brook is located within the Keene flood plain and is affected by backwater during Ashuelot River flood periods. Therefore, Beaver Brook Lake will also be regulated to supplement Surry Mountain and Otter Brook regulations when Ashuelot River floodflows are anticipated or experienced. Additional information on the regulation procedures of the Surry Mountain and Otter Brook projects can be obtained from the "Connecticut River Master Manual of Regulation, Appendix E, Ashuelot River Watershed, dated January 1972."

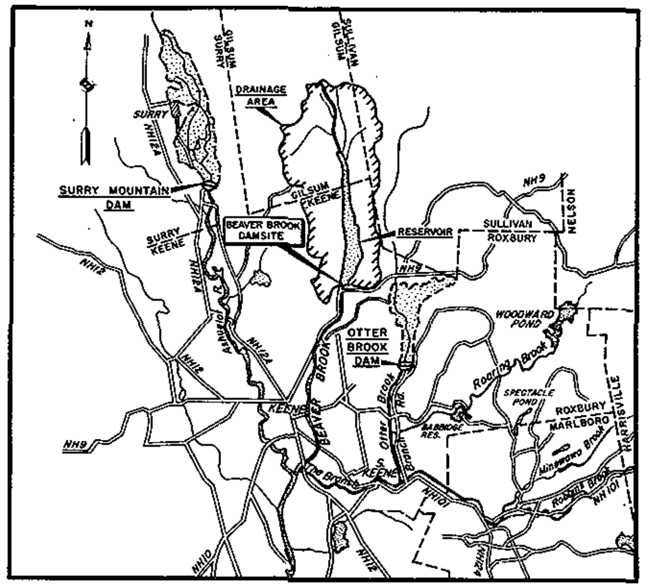
c. Recreation-water supply. In the years immediately following the construction of the project, a permanent pool will be maintained at approximately elevation 811.5 feet, msl for recreation purposes, consistent with State of New Hampshire desires. However, in future years when Keene's water needs increase, the storage will be used for water supply, and releases from the 3,000 acre-foot water supply pool will then be regulated for the city of Keene to meet their needs.

d. Minimum downstream releases. The December 1966 Interim Report did not consider minimum downstream releases. However, a release of about 1 cfs is planned in order to insure that the stream does not dry up during drought periods, during periods when streamflow is being stored, or when diversion out of the reservoir occurs. Maintaining a minimum flow of 1 cfs from the water supply storage alone would reduce the dependable water supply yield considerably during drought periods. Therefore, in order to assist Keene in meeting this 1 cfs obligation, it is planned that up to 730 acre-feet of flood control storage, equivalent to 2.3 inches of runoff, will be utilized seasonally in the late spring and summer months, subject to a predetermined rule curve shown on plate 1-16. During the fall and winter months, downstream releases would be made from the water supply pool. The full utilization of this seasonal use storage is dependent upon sufficient runoff. In critical dry years when the reservoir does not fill to elevation 815 (top of seasonal storage), and the city withdraws at a normal rate during the spring runoff, the low flow requirement of 1 cfs will be reduced, depending upon the severity of the drought. Because of the seasonal use of flood control storage, Corps personnel will be operationally involved.

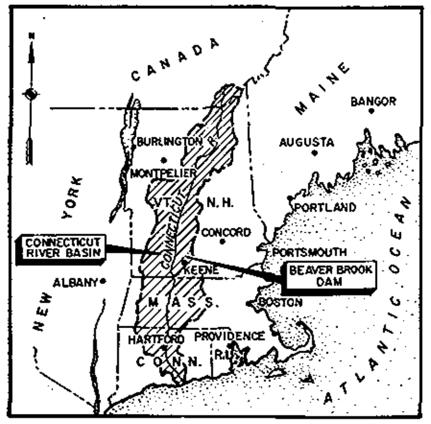
Special provisions will be included in a contract with the city to insure that (a) they will draw down a portion of the water supply in the summer months, or (b) the Corps will draw down the pool to the rule curve. Simulated Beaver Lake stages and releases for wet, dry and normal four year periods are shown on plates 1-17, 1-18 and 1-19.



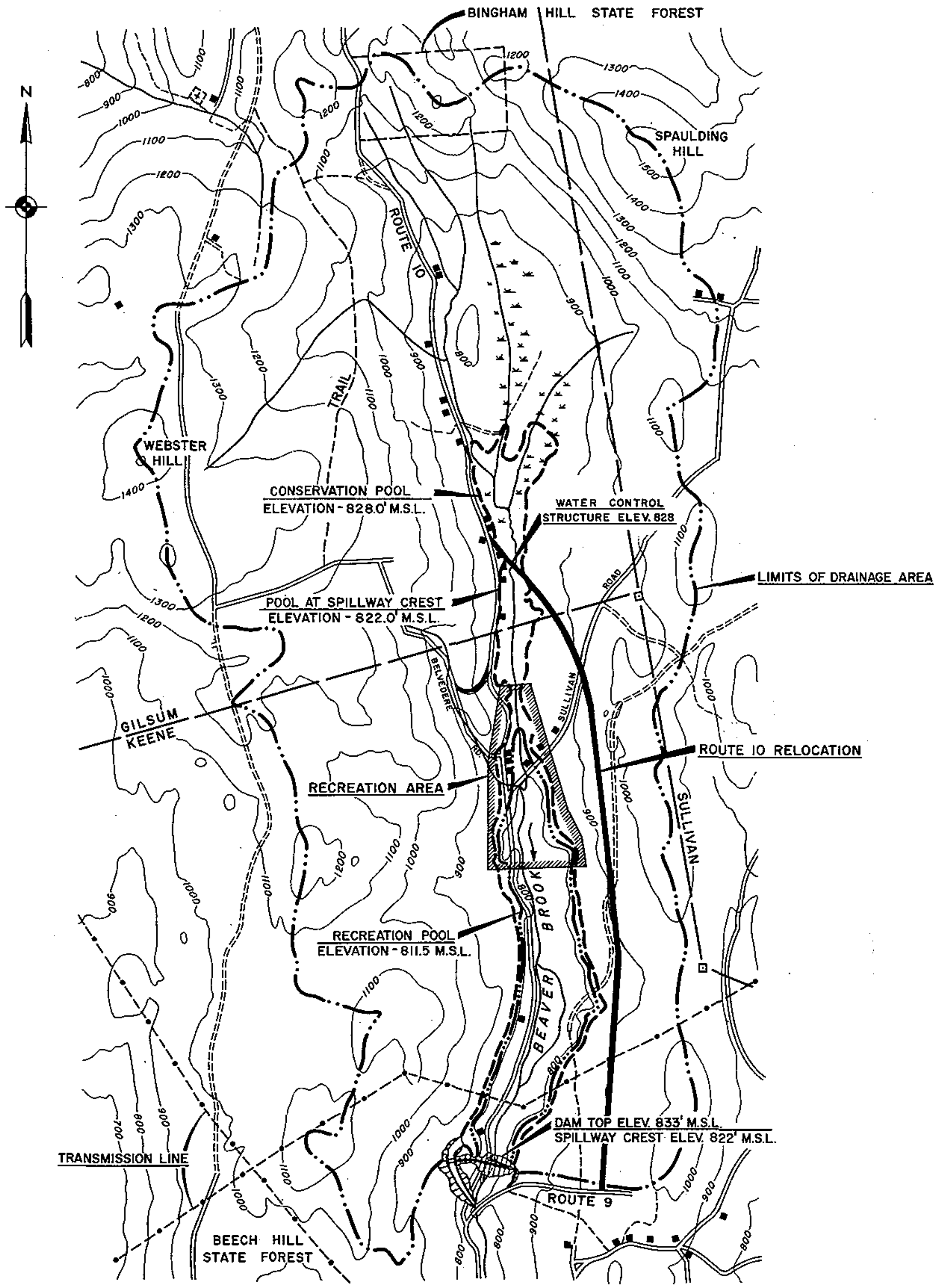
LOCATION MAP
CANADA
NEW YORK
VERMONT
NEW HAMPSHIRE
MAINE
MASSACHUSETTS
CONNECTICUT
RHODE ISLAND
CONNECTICUT RIVER
ASHUELOT RIVER WATERSHED
CONCORD
BARRE
HOLYOKE
WORCESTER
BOSTON
SPRINGFIELD
HARTFORD
PROVIDENCE
NEW HAVEN
LONG ISLAND SOUND
ATLANTIC OCEAN
LEGEND
TELEMARK GAGE
RECORDING GAGE
NON-RECORDING GAGE
RECORDING RAINFALL GAGE
NON-RECORDING RAINFALL GAGE
SNOW SURVEY COURSE
AUTOMATIC WATER QUALITY MONITOR
POSSIBLE ICE JAM AREA
N
7.8 MILES TO BRADFORD
May Pond
Long Pond
Sand Pond
MITTEN LAKE
Ashuelot Pond
WILLIAMS RIVER
NORTH WALPOLE
BELLOWS FALLS
BELLOWS FALLS DAM
SAXTONS RIVER
COLD RIVER
LAKE WARREN
VILLAGE POND
MARLOW
ASHUELOT RIVER
Grassy Brk.
Thompson Brk.
Dart Brk.
GILSUM
Great Brk.
Center Pond
SURRY MOUNTAIN LAKE
GRANITE LAKE
Ellis Res.
MUNSONVILLE
BEAVER BROOK LAKE (UNDER DESIGN)
Otter Brook
OTTER BROOK LAKE
SILVER LAKE
Woodward Pond
Roaring Brk.
CONNECTICUT RIVER
Partridge Brk.
FAULKNER AND COLONY DAM
KEENE
KEENE FLOOD PLAIN
Branch
Minnewawa Brk.
HOWE RES.
Dublin Pond
4.¼ MILES TO MAC DOWELL DAM
VERMONT
NEW HAMPSHIRE
SPOFFORD LAKE
WEST RIVER
California Brk.
WEST SWANZEY DAM
South Branch Ashuelot R.
MONADNOCK MTN.
SWANZEY LAKE
HONEY HILL LAKE (PROPOSED)
BRATTLEBORO
WESTPORT
TROY
Quarry Brk.
Kilburn Brk.
Tufts Brk.
Broad Brk.
Pauls Brk.
HINSDALE
ASHUELOT
ASHUELOT RIVER
WINCHESTER
Roaring Brook
Mirey Brk.
VERNON DAM
VERNON
VERMONT
MASSACHUSETTS
NEW HAMPSHIRE
MASSACHUSETTS
MONTAGUE CITY GAGE 16 MILES DOWNSTREAM FROM STATE LINE
SCALE IN MILES
1 0 1 2 3 4
CONNECTICUT RIVER FLOOD CONTROL
ASHUELOT RIVER
WATERSHED MAP
DEPARTMENT OF THE ARMY - NEW ENGLAND DIVISION
CORPS OF ENGINEERS - WALTHAM, MASS.
NOVEMBER 1971



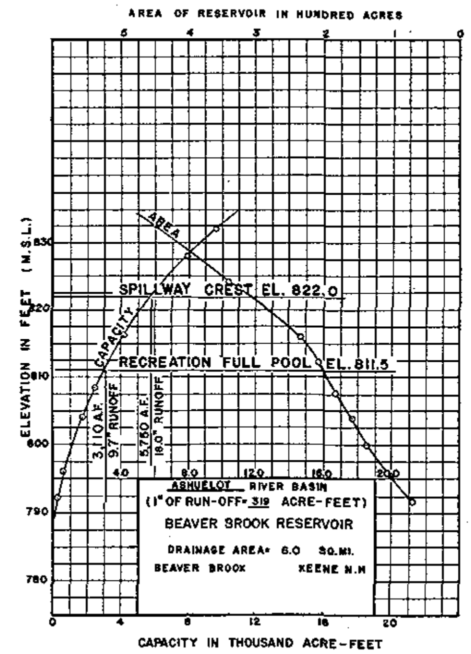
VICINITY MAP



LOCATION MAP



RESERVOIR PLAN



AREA AND CAPACITY CURVES

NOTE:

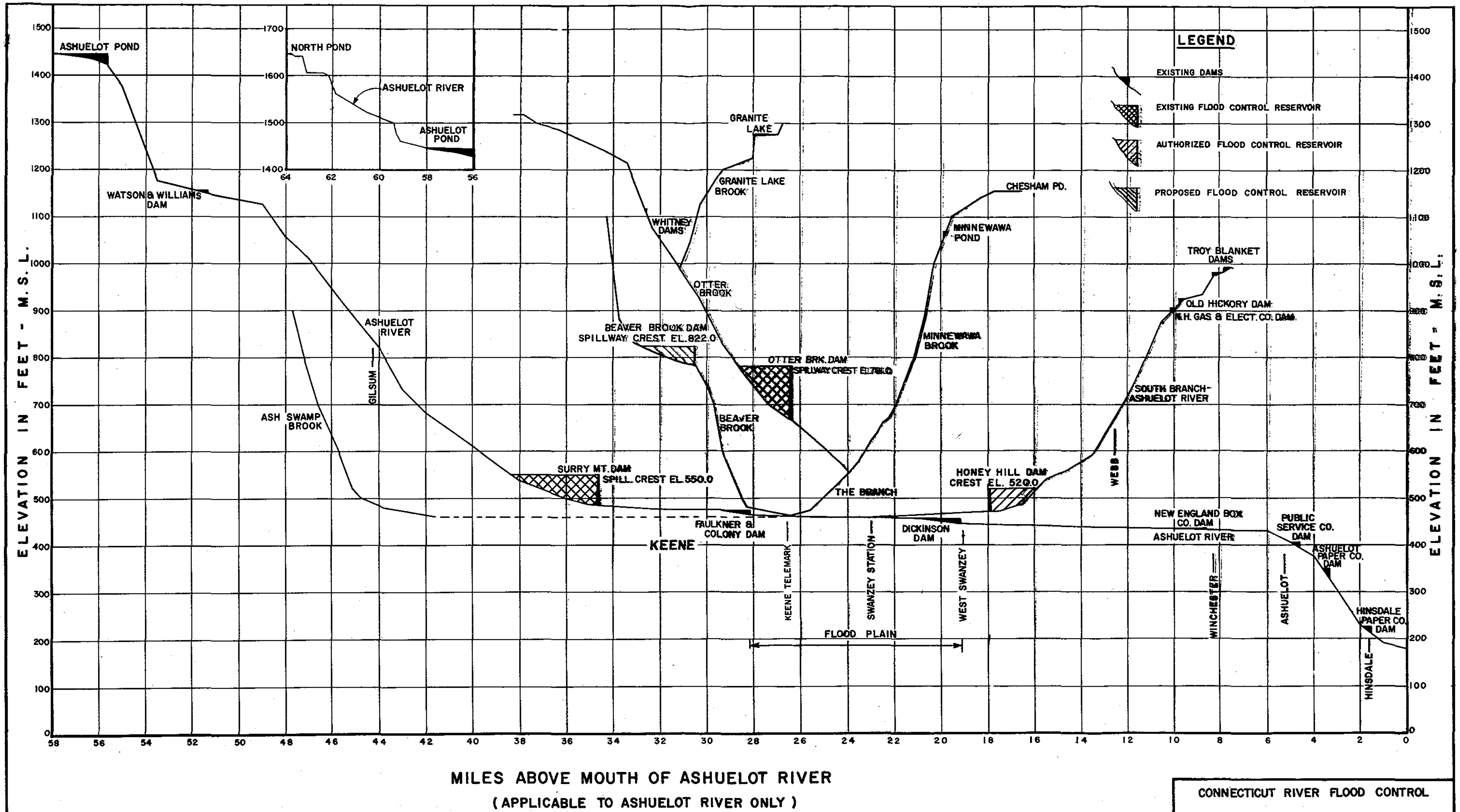
Route 10 in reservoir area to be relocated.
115 KV Transmission line to be relocated (6,000 L.F.).
Elevations refer to Mean Sea Level Datum.
Topography is based on Nov.-Dec. 1964 and Jan. 1965 survey by U.S. Army Corps of Engineers.

CONNECTICUT RIVER FLOOD CONTROL
KEENE, NEW HAMPSHIRE

BEAVER BROOK LAKE

DRAINAGE AREA AND
RESERVOIR PLAN

NEW ENGLAND DIVISION, WALTHAM, MASS.
MARCH 1972



CONNECTICUT RIVER FLOOD CONTROL

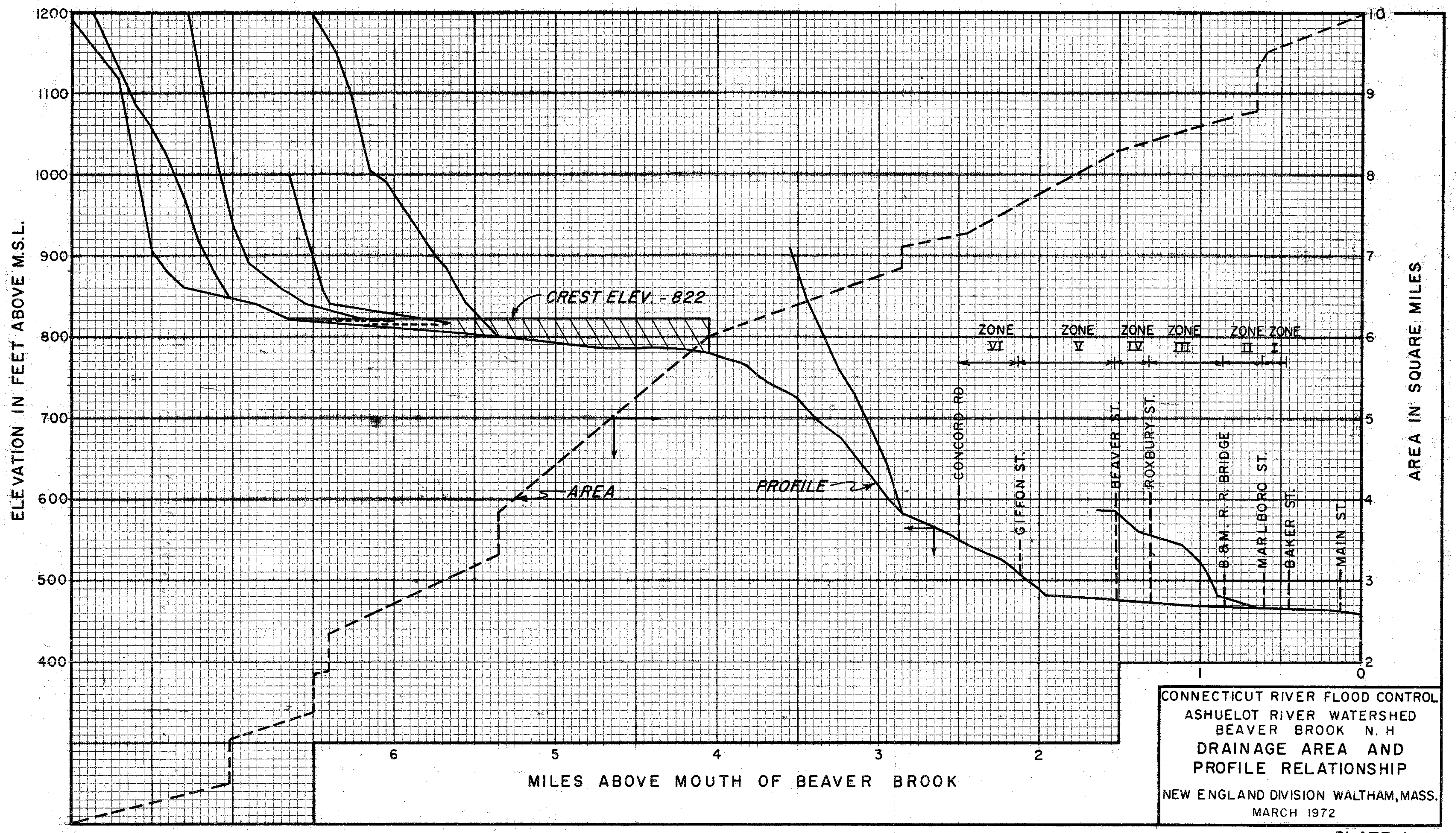
ASHUELOT RIVER BASIN
PROFILES

ASHUELOT RIVER AND TRIBUTARIES

NEW ENGLAND DIVISION WALTHAM, MASS.

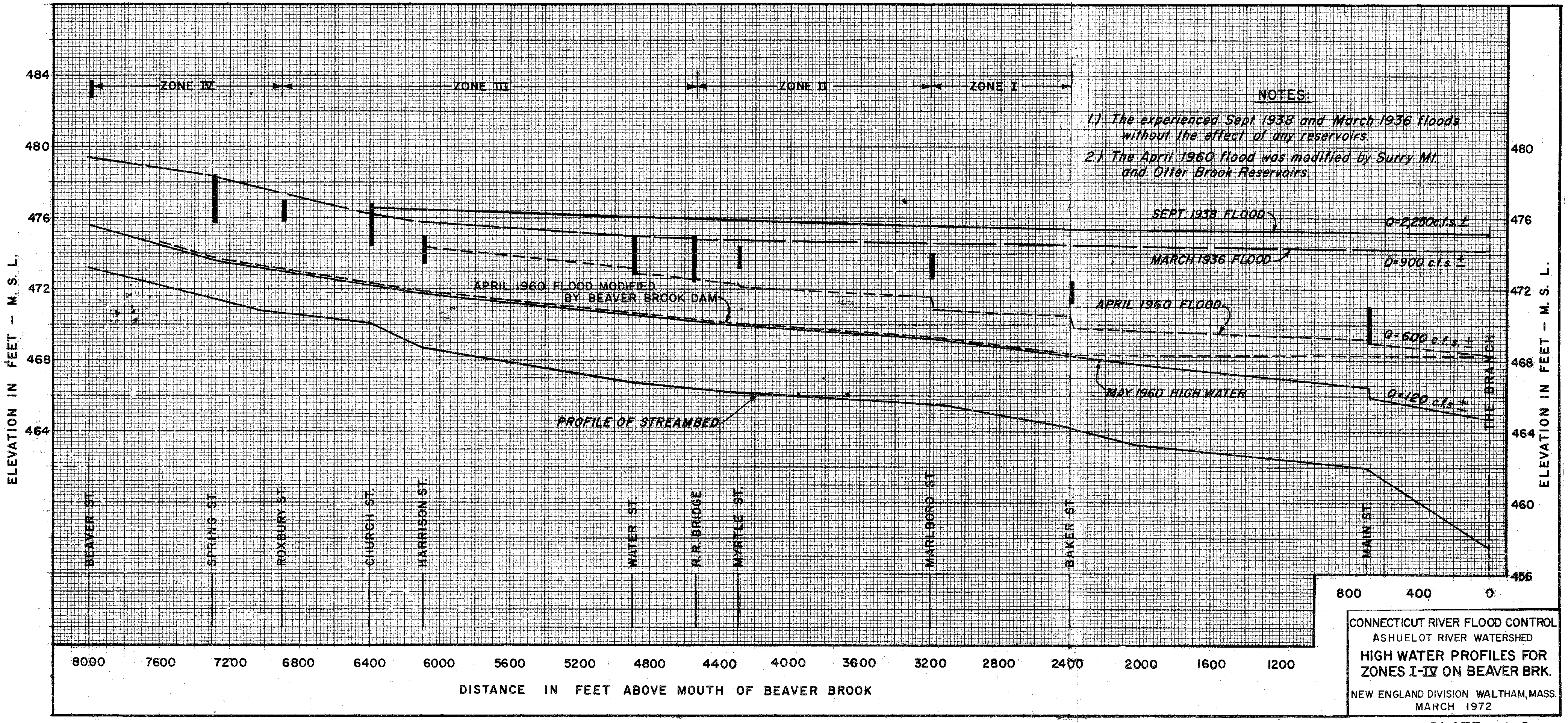
NOVEMBER 1966

PLATE I-3



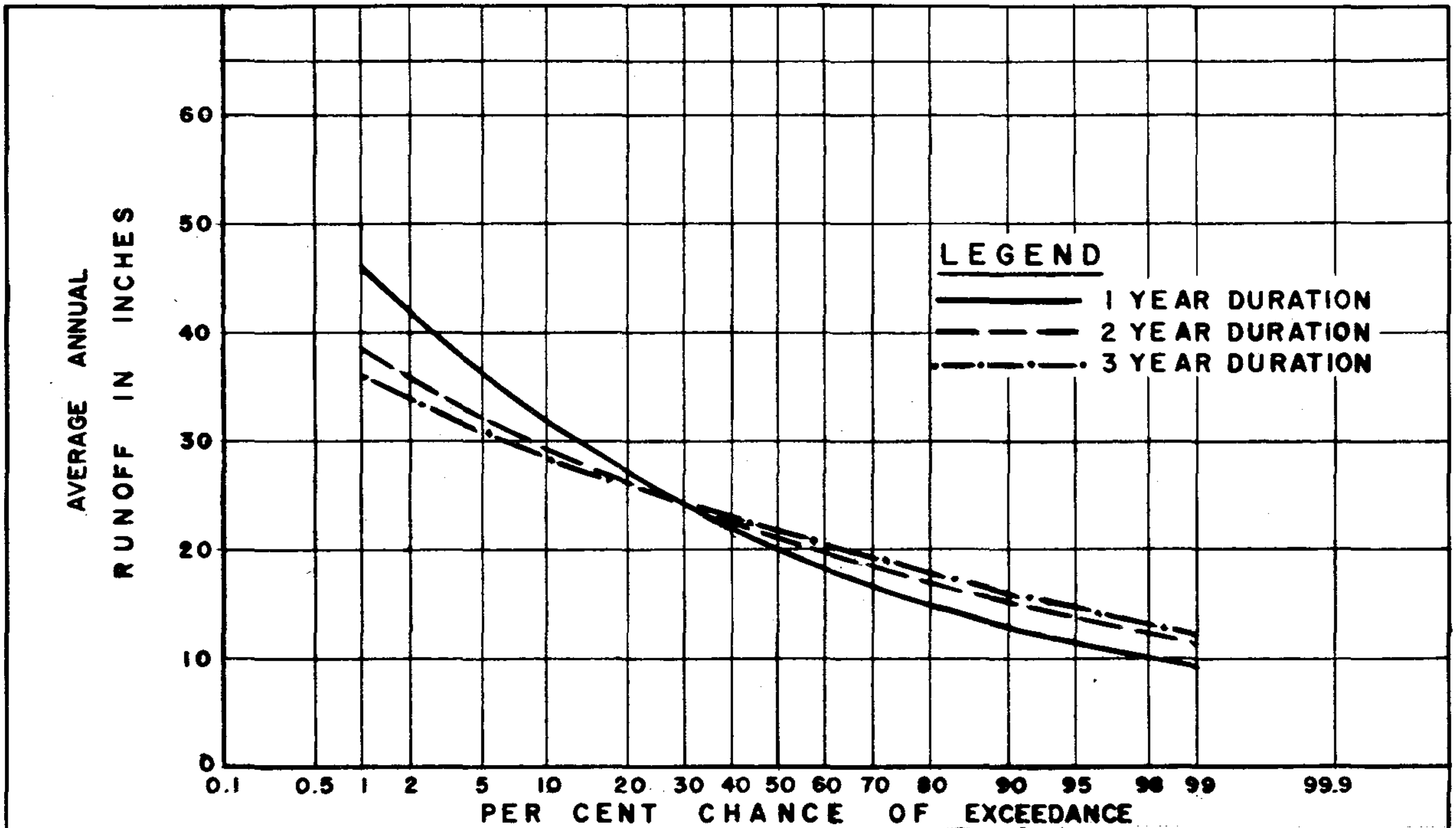
CONNECTICUT RIVER FLOOD CONTROL
ASHUELOT RIVER WATERSHED
BEAVER BROOK N. H
DRAINAGE AREA AND
PROFILE RELATIONSHIP
NEW ENGLAND DIVISION WALTHAM, MASS.
MARCH 1972

PLATE I-4



CONNECTICUT RIVER FLOOD CONTROL
ASHUELOT RIVER WATERSHED
HIGH WATER PROFILES FOR ZONES I-IV ON BEAVER BRK.
NEW ENGLAND DIVISION WALTHAM, MASS.
MARCH 1972

PLATE I-5



CONNECTICUT RIVER FLOOD CONTROL
PRIEST BROOK
AVERAGE ANNUAL RUN-OFF CURVES
MILLERS RIVER BASIN
MASSACHUSETTS
MARCH 1972

PLATE I-6

HIGH FLOW DURATIONS FOR SOUTH BRANCH ASHUELOT AT WEBB

FLOWS HAVE BEEN CHANGED BY A RATIO OF 0.000 STARTING WITH BEGINNING OF RECORD
FLOWS HAVE BEEN CHANGED BY A RATIO OF 0.000 STARTING WITH YEAR 1920

HIGHEST MEAN DISCHARGE, IN CFS, FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS
BEGINNING MONTH OCT. ENDING MONTH SEP.

YEAR	1.	2.	3.	5.	7.	10.	15.	30.
1921	650.00	545.00	442.33	312.60	262.14	236.40	234.00	184.67
1922	460.00	427.50	371.67	363.00	330.71	304.00	274.33	238.27
1923	805.00	647.50	606.67	548.00	489.29	409.00	315.20	254.50
1924	740.00	620.00	520.00	420.00	367.14	330.50	307.40	233.33
1925	945.00	710.00	626.67	445.40	359.29	277.20	226.07	207.30
1926	471.00	391.50	363.67	323.20	281.00	248.50	239.33	199.93
1927	478.00	476.00	456.67	420.40	386.00	335.80	268.27	179.77
1928	2260.00	1408.00	1021.00	699.60	536.43	405.80	341.13	248.63
1929	792.00	641.50	553.33	488.00	456.71	472.80	410.20	280.53
1930	445.00	321.00	270.00	201.40	165.14	140.10	124.87	115.57
1931	638.00	538.00	486.67	422.00	376.86	367.40	330.93	232.83
1932	915.00	664.00	566.33	451.60	388.29	341.00	318.53	209.63
1933	658.00	655.50	635.00	601.60	525.14	442.00	431.80	324.47
1934	612.00	567.00	467.00	390.80	360.14	329.90	320.53	270.30
1935	517.00	385.50	323.67	252.00	205.71	165.40	147.93	116.67
1936	2220.00	1695.00	1351.00	1022.80	874.86	824.10	664.87	434.17
1937	376.00	309.50	261.00	214.20	197.57	184.80	181.40	168.27
1938	3070.00	2130.00	1776.67	1209.20	918.28	684.50	483.33	251.95
1939	520.00	425.00	357.33	311.80	284.00	288.80	260.53	210.93
1940	930.00	925.00	771.67	690.60	593.14	501.00	452.33	368.47
1941	340.00	320.00	300.00	236.00	195.71	154.80	121.07	93.77
1942	1000.00	754.00	571.33	406.80	321.86	296.40	287.00	208.87
1943	339.00	300.50	248.67	211.40	191.86	184.30	178.20	161.97
1944	884.00	690.00	580.33	408.60	338.57	263.40	221.93	202.73
1945	547.00	432.50	394.33	396.20	358.57	308.60	283.13	216.60
1946	680.00	564.50	476.33	368.40	317.71	290.30	234.80	165.93
1947	440.00	382.50	362.67	310.00	292.86	272.70	236.47	207.40
1948	788.00	716.50	672.67	609.80	534.29	497.10	404.87	271.73
1949	450.00	425.00	366.67	278.00	224.57	211.30	174.00	112.80
1950	449.00	405.00	344.33	275.60	271.00	274.40	223.40	182.97
1951	1150.00	769.00	577.33	557.80	475.00	388.40	313.60	235.23
1952	643.00	559.00	504.33	425.60	388.43	341.60	294.20	211.60
1953	680.00	540.00	463.33	417.00	402.29	353.80	305.47	268.23
1954	660.00	510.00	411.67	312.20	251.57	205.40	166.73	154.63
1955	400.00	385.00	337.67	272.60	233.14	191.70	164.33	156.20
1956	1000.00	836.00	719.00	579.80	489.14	417.20	438.67	351.13
1957	330.00	315.00	280.00	226.00	190.00	154.00	132.13	123.97
1958	603.00	594.00	581.00	548.20	515.14	477.10	412.33	335.90
1959	1130.00	826.00	697.33	549.40	453.00	399.90	316.40	223.03
1960	1830.00	1374.50	1181.67	915.80	870.00	713.70	573.13	373.43
1961	367.00	343.50	289.00	257.00	234.43	225.20	215.00	192.43
1962	691.00	645.00	578.33	464.60	388.71	423.00	357.07	232.60
1963	656.00	555.50	512.00	446.20	424.71	417.70	343.53	222.50
1964	522.00	456.00	398.00	324.60	284.86	266.00	223.53	168.77
1965	256.00	233.00	199.67	185.80	173.00	151.10	127.07	89.73
1966	720.00	565.00	460.33	352.00	296.43	247.10	199.20	138.70
1967	750.00	651.00	557.33	447.20	359.00	332.00	281.33	233.33
1968	905.00	902.50	804.67	716.20	697.57	562.10	429.67	248.17
1969	902.00	800.00	706.33	609.20	596.00	525.00	449.00	333.70
1970	738.00	609.50	523.00	379.40	318.86	312.90	303.20	254.83

HIGH FLOW DURATIONS FOR SOUTH BRANCH ASHUELOT AT WEBB

DURATION IN CONSECUTIVE DAYS
BEGINNING MONTH OCT. ENDING MONTH SEP.

ANNUAL HIGHEST MEAN DISCHARGE

PLOT.POS.	1.	2.	3.	5.	7.	10.	15.	30.
1.37	256.00	233.00	199.67	185.80	165.14	140.10	121.07	89.73
3.36	330.00	300.50	248.67	201.40	173.00	151.10	124.87	93.77
5.34	339.00	309.50	261.00	211.40	190.00	154.00	127.07	112.80
7.33	340.00	315.00	270.00	214.20	191.86	154.80	132.13	115.57
9.31	367.00	320.00	280.00	226.00	195.71	165.40	147.93	116.67
11.29	376.00	321.00	289.00	236.00	197.57	184.30	164.33	123.97
13.28	400.00	343.50	300.00	252.00	205.71	184.80	166.73	138.70
15.26	440.00	382.50	323.67	257.00	224.57	191.70	174.00	154.63
17.25	445.00	385.00	337.67	272.60	233.14	205.40	178.20	156.20
19.23	449.00	385.50	344.33	275.60	234.43	211.30	181.40	161.97
21.22	450.00	391.50	357.33	278.00	251.57	225.20	199.20	165.93
23.20	460.00	405.00	362.67	310.00	262.14	236.40	215.00	168.27
25.19	471.00	425.00	363.67	311.80	271.00	247.10	221.93	168.77
27.17	478.00	425.00	366.67	312.20	281.00	248.50	223.40	179.77
29.16	517.00	427.50	371.67	312.60	284.00	263.40	223.53	182.97
31.14	520.00	432.50	394.33	323.20	284.86	266.00	226.07	184.67
33.13	522.00	456.00	398.00	324.60	292.86	272.70	234.00	192.43
35.11	547.00	476.00	411.67	352.00	296.43	274.40	234.80	199.93
37.09	603.00	510.00	442.33	363.00	317.71	277.20	236.47	202.73
39.08	612.00	538.00	456.67	368.40	318.86	288.80	239.33	207.30
41.06	638.00	540.00	460.33	379.40	321.86	290.30	260.53	207.40
43.05	643.00	545.00	463.33	390.80	330.71	296.40	268.27	208.87
45.03	650.00	555.50	467.00	396.20	338.57	304.00	274.33	209.63
47.02	656.00	559.00	476.33	406.80	358.57	308.60	281.33	210.93
49.00	658.00	564.50	486.67	408.60	359.00	312.90	283.13	211.60
50.99	660.00	565.00	504.33	417.00	359.29	329.90	287.00	216.60
52.97	680.00	567.00	512.00	420.00	360.14	330.50	294.20	222.50
54.96	680.00	594.00	520.00	420.40	367.14	332.00	303.20	223.03
56.94	691.00	609.50	523.00	422.00	376.86	335.80	305.47	232.60
58.93	720.00	620.00	553.33	425.60	386.00	341.00	307.40	232.83
60.91	738.00	641.50	557.33	445.40	388.29	341.60	313.60	233.33
62.89	740.00	645.00	566.33	446.20	388.43	353.80	315.20	233.33
64.88	750.00	647.50	571.33	447.20	388.71	367.40	316.40	235.23
66.86	788.00	651.00	577.33	451.60	402.29	388.40	318.53	238.27
68.85	792.00	655.50	578.33	464.60	424.71	399.90	320.53	248.17
70.83	805.00	664.00	580.33	488.00	453.00	405.80	330.93	248.63
72.82	884.00	690.00	581.00	548.00	456.71	409.00	341.13	251.95
74.80	902.00	710.00	606.67	548.20	475.00	417.20	343.53	254.50
76.79	905.00	716.50	626.67	549.40	489.14	417.70	357.07	254.83
78.77	915.00	754.00	635.00	557.80	489.29	423.00	404.87	268.23
80.76	930.00	769.00	672.67	579.80	515.14	442.00	410.20	270.30
82.74	945.00	800.00	697.33	601.60	525.14	472.80	412.33	271.73
84.73	1000.00	826.00	706.33	609.20	534.29	477.10	429.67	280.53
86.71	1000.00	836.00	719.00	609.80	536.43	497.10	431.80	324.47
88.70	1130.00	902.50	771.67	690.60	593.14	501.00	438.67	333.70
90.68	1150.00	925.00	804.67	699.60	596.00	525.00	449.00	335.90
92.66	1830.00	1374.50	1021.00	716.20	697.57	562.10	452.33	351.13
94.65	2220.00	1408.00	1181.67	915.80	870.00	684.50	483.33	368.47
96.63	2260.00	1695.00	1351.00	1022.80	874.86	713.70	573.13	373.43
98.62	3070.00	2130.00	1776.67	1209.20	918.28	824.10	664.87	434.17

HIGH FLOW DURATIONS FOR SOUTH BRANCH ASHUELOT AT WEBB

BEGINNING MONTH OCT. ENDING MONTH SEP.

HIGH FLOW FREQUENCY STATISTICS

DURATION	MEAN LOG	STD.DEV.	ADJ.STD.DEV.	SKEW
1.	2.8335	0.218	0.213	0.85
2.	2.7580	0.194	0.200	0.71
3.	2.6940	0.188	0.193	0.57
5.	2.6099	0.181	0.184	0.34
7.	2.5512	0.182	0.179	0.27
10.	2.4985	0.180	0.173	0.03
15.	2.4363	0.174	0.167	-0.18
30.	2.3217	0.151	0.157	-0.42

WATER RESOURCES DEVELOPMENT PROJECT
CONNECTICUT RIVER BASIN
BEAVER BROOK LAKE
HIGH-FLOW DURATION
SOUTH BRANCH
ASHUELOT RIVER
NEW ENGLAND DIVISION WALTHAM, MASS.
MARCH 1972

PLATE I-7

LOW FLOW DURATIONS FOR SOUTH BRANCH ASHUELOT AT WEBB

FLOWS HAVE BEEN CHANGED BY A RATIO OF 0.000 STARTING WITH BEGINNING OF RECORD
FLOWS HAVE BEEN CHANGED BY A RATIO OF 0.000 STARTING WITH YEAR 1920

LOWEST MEAN DISCHARGE, IN CFS, FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS
BEGINNING MONTH APR. ENDING MONTH MAR.

YEAR	1.	2.	3.	5.	7.	10.	15.	30.
1921	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.47
1922	5.80	8.00	8.07	8.48	9.63	9.34	10.76	15.96
1923	2.70	2.70	2.83	3.38	3.76	4.47	5.13	5.81
1924	1.20	1.45	1.43	1.54	1.76	1.98	2.30	3.21
1925	1.00	1.10	1.13	1.16	1.56	1.78	2.17	4.40
1926	0.40	0.40	0.40	0.46	0.50	0.53	2.08	3.01
1927	1.20	1.20	1.33	4.74	5.00	5.24	7.51	14.88
1928	3.00	4.00	5.33	5.80	6.43	6.90	10.73	19.63
1929	0.80	0.95	1.10	1.34	1.57	1.73	2.33	2.79
1930	1.00	1.00	1.03	1.08	1.10	1.73	1.83	2.10
1931	2.00	3.65	3.77	3.80	4.24	4.67	4.97	5.77
1932	0.90	1.00	1.03	1.10	1.14	1.16	1.57	1.86
1933	1.50	1.55	1.67	2.52	3.26	3.39	3.78	4.53
1934	1.60	1.70	1.80	1.82	1.93	1.96	2.37	3.23
1935	4.70	4.70	4.70	5.02	5.11	5.22	5.41	6.62
1936	1.60	1.60	1.73	2.26	2.17	2.41	3.10	3.84
1937	1.90	1.95	1.97	2.14	3.17	3.15	4.29	4.87
1938	3.00	5.00	5.87	11.12	12.80	13.65	14.49	18.89
1939	2.20	2.20	2.27	2.40	2.49	2.62	3.29	4.88
1940	1.90	2.05	2.23	2.66	2.90	3.44	4.83	4.85
1941	1.70	1.70	1.80	2.04	2.47	3.15	3.37	5.02
1942	4.10	4.60	5.57	7.02	7.63	8.37	8.69	13.56
1943	1.20	1.85	1.87	1.88	2.26	2.52	2.85	4.34
1944	1.30	1.40	1.43	2.26	3.24	3.53	4.20	4.82
1945	7.20	7.20	7.37	7.58	7.78	8.29	10.45	11.85
1946	5.30	5.50	5.63	6.02	6.34	6.80	7.62	13.01
1947	1.30	1.40	1.43	1.96	2.79	3.12	4.42	5.58
1948	2.10	2.10	2.10	2.24	2.47	2.38	2.83	3.71
1949	1.60	1.70	1.77	1.88	2.00	2.25	2.91	3.88
1950	3.00	3.10	3.37	3.50	3.59	3.73	3.89	5.62
1951	9.10	9.35	9.37	10.54	11.81	12.87	17.27	22.37
1952	2.10	2.20	2.37	2.64	3.16	3.78	4.43	5.91
1953	2.40	2.40	2.40	2.40	2.43	2.44	2.49	2.59
1954	4.00	4.10	4.30	4.88	5.34	6.84	7.65	13.72
1955	2.70	2.90	3.30	3.78	4.01	3.86	4.33	4.73
1956	2.50	2.85	3.33	3.98	4.51	4.73	4.76	5.29
1957	1.90	2.00	2.03	2.16	2.30	2.31	2.39	2.55
1958	4.10	4.20	4.40	4.72	5.01	5.40	6.07	6.70
1959	6.20	6.20	6.20	6.32	6.37	6.83	7.88	10.27
1960	1.40	1.55	1.90	2.34	2.67	3.45	4.48	8.14
1961	3.80	3.80	3.93	4.30	4.36	4.45	4.77	6.82
1962	3.00	3.10	3.17	3.42	3.67	3.90	4.06	5.64
1963	2.60	2.60	2.60	2.76	2.87	2.86	2.93	3.25
1964	2.00	2.05	2.07	2.08	2.10	2.12	2.17	2.50
1965	2.50	2.50	2.57	2.64	2.70	2.95	3.53	4.54
1966	0.70	0.80	0.87	1.00	1.10	1.26	1.50	1.98
1967	3.30	3.35	3.43	3.64	3.74	3.81	4.53	6.15
1968	1.50	1.50	1.70	1.88	2.00	2.13	2.35	3.34
1969	7.30	7.30	7.30	7.34	7.56	7.89	8.54	8.86

LOW FLOW DURATIONS FOR SOUTH BRANCH ASHUELOT AT WEBB

DURATION IN CONSECUTIVE DAYS
BEGINNING MONTH APR. ENDING MONTH MAR.

PLOT.POS. ANNUAL LOWEST MEAN DISCHARGE

PLOT.POS.	1.	2.	3.	5.	7.	10.	15.	30.
1.40	0.40	0.40	0.40	0.46	0.50	0.53	1.50	1.86
3.42	0.70	0.80	0.87	1.00	1.10	1.16	1.57	1.98
5.45	0.80	0.95	1.03	1.08	1.10	1.26	1.83	2.10
7.47	0.90	1.00	1.03	1.10	1.14	1.73	2.08	2.50
9.50	1.00	1.00	1.10	1.16	1.56	1.73	2.17	2.55
11.52	1.00	1.10	1.13	1.34	1.57	1.78	2.17	2.59
13.55	1.20	1.20	1.33	1.54	1.76	1.96	2.30	2.79
15.57	1.20	1.40	1.43	1.82	1.93	1.98	2.33	3.01
17.60	1.20	1.40	1.43	1.88	2.00	2.12	2.35	3.21
19.62	1.30	1.45	1.43	1.88	2.00	2.13	2.37	3.23
21.65	1.30	1.50	1.67	1.88	2.10	2.25	2.39	3.25
23.67	1.40	1.55	1.70	1.96	2.17	2.31	2.49	3.34
25.70	1.50	1.55	1.73	2.04	2.26	2.38	2.83	3.47
27.72	1.50	1.60	1.77	2.08	2.30	2.41	2.85	3.71
29.75	1.60	1.70	1.80	2.14	2.43	2.44	2.91	3.84
31.77	1.60	1.70	1.80	2.16	2.47	2.52	2.93	3.88
33.80	1.60	1.70	1.87	2.24	2.47	2.62	3.00	4.34
35.82	1.70	1.85	1.90	2.26	2.49	2.86	3.10	4.40
37.85	1.90	1.95	1.97	2.26	2.67	2.95	3.29	4.53
39.87	1.90	2.00	2.03	2.34	2.70	3.00	3.37	4.54
41.90	1.90	2.05	2.07	2.40	2.79	3.12	3.53	4.73
43.92	2.00	2.05	2.10	2.40	2.87	3.15	3.78	4.82
45.95	2.00	2.10	2.23	2.52	2.90	3.15	3.89	4.85
47.97	2.10	2.20	2.27	2.64	3.00	3.39	4.06	4.87
49.99	2.10	2.20	2.37	2.64	3.16	3.44	4.20	4.88
52.02	2.20	2.40	2.40	2.66	3.17	3.45	4.29	5.02
54.04	2.40	2.50	2.57	2.76	3.24	3.53	4.33	5.29
56.07	2.50	2.60	2.60	3.00	3.26	3.73	4.42	5.58
58.09	2.50	2.70	2.83	3.38	3.59	3.78	4.43	5.62
60.12	2.60	2.85	3.00	3.42	3.67	3.81	4.48	5.64
62.14	2.70	2.90	3.17	3.50	3.74	3.86	4.53	5.77
64.17	2.70	3.00	3.30	3.64	3.76	3.90	4.76	5.81
66.19	3.00	3.10	3.33	3.78	4.01	4.45	4.77	5.91
68.22	3.00	3.10	3.37	3.80	4.24	4.47	4.83	6.15
70.24	3.00	3.35	3.43	3.98	4.36	4.67	4.97	6.62
72.27	3.00	3.65	3.77	4.30	4.51	4.73	5.13	6.70
74.29	3.00	3.80	3.93	4.72	5.00	5.22	5.41	6.82
76.32	3.30	4.00	4.30	4.74	5.01	5.24	6.07	8.14
78.34	3.80	4.10	4.40	4.88	5.11	5.40	7.51	8.86
80.37	4.00	4.20	4.70	5.02	5.34	6.80	7.62	10.27
82.39	4.10	4.60	5.33	5.80	6.34	6.83	7.65	11.85
84.42	4.10	4.70	5.57	6.02	6.37	6.84	7.88	13.01
86.44	4.70	5.00	5.63	6.32	6.43	6.90	8.54	13.56
88.47	5.30	5.50	5.87	7.02	7.56	7.89	8.69	13.72
90.49	5.80	6.20	6.20	7.34	7.63	8.29	10.45	14.88
92.52	6.20	7.20	7.30	7.58	7.78	8.37	10.73	15.96
94.54	7.20	7.30	7.37	8.48	9.63	9.34	10.76	18.89
96.57	7.30	8.00	8.07	10.54	11.81	12.87	14.49	19.63
98.59	9.10	9.35	9.37	11.12	12.80	13.65	17.27	22.37

LOW FLOW DURATIONS FOR SOUTH BRANCH ASHUELOT AT WEBB

BEGINNING MONTH APR. ENDING MONTH MAR.

LOW FLOW FREQUENCY STATISTICS

DURATION	MEAN LOG	STD.DEV.	ADJ.STD.DEV.	SKEW
1.	0.3467	0.281	0.286	-0.02
2.	0.3820	0.282	0.281	-0.07
3.	0.4056	0.283	0.279	-0.12
5.	0.4659	0.282	0.275	-0.12
7.	0.5086	0.277	0.273	-0.17
10.	0.5435	0.271	0.271	-0.17
15.	0.6208	0.249	0.268	0.47
30.	0.7399	0.272	0.263	0.53

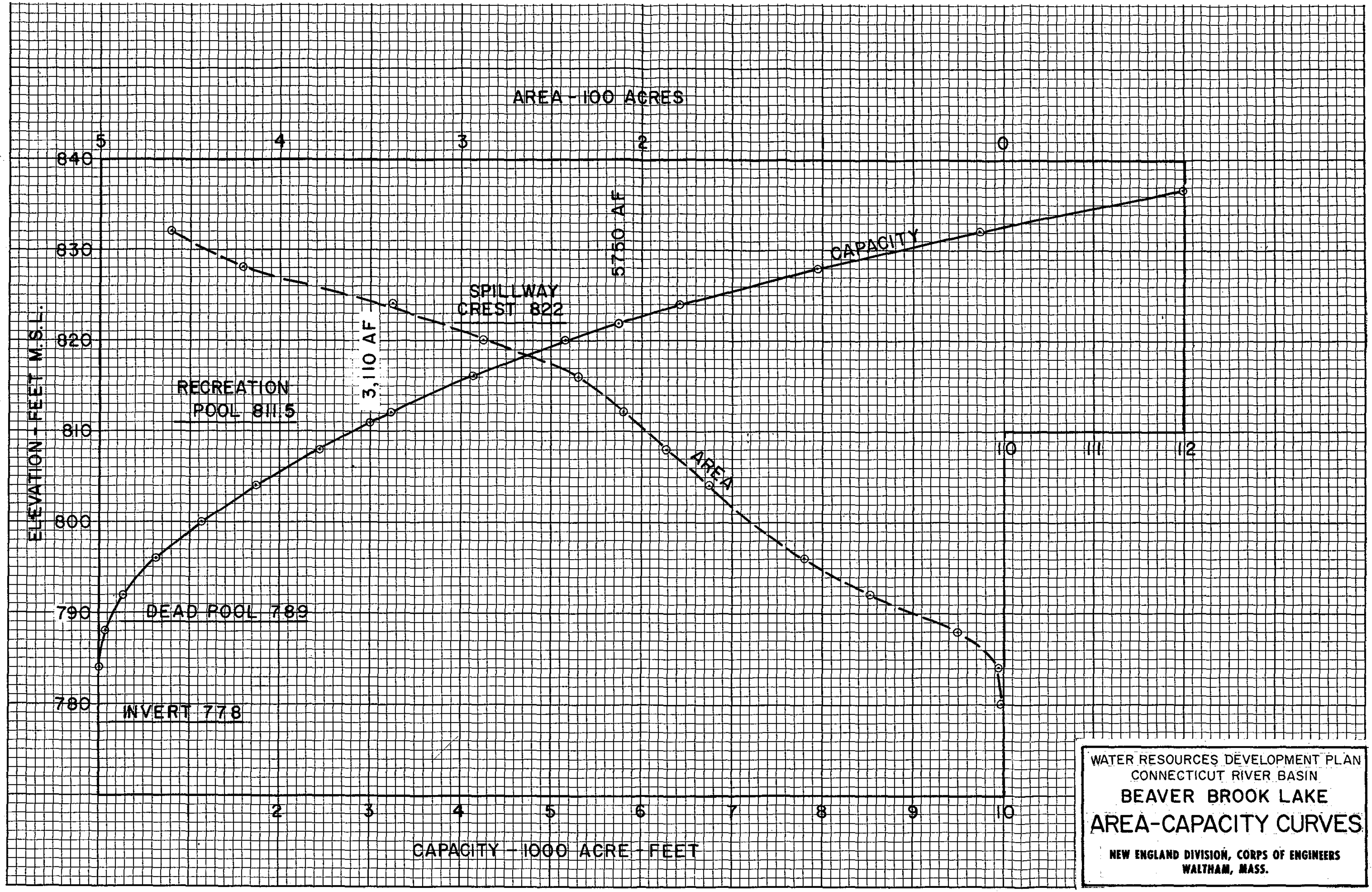
WATER RESOURCES DEVELOPMENT PROJECT
CONNECTICUT RIVER BASIN

BEAVER BROOK LAKE

LOW-FLOW DURATION
SOUTH BRANCH
ASHUELOT RIVER

NEW ENGLAND DIVISION WALTHAM, MASS.
MARCH 1972

PLATE I-8



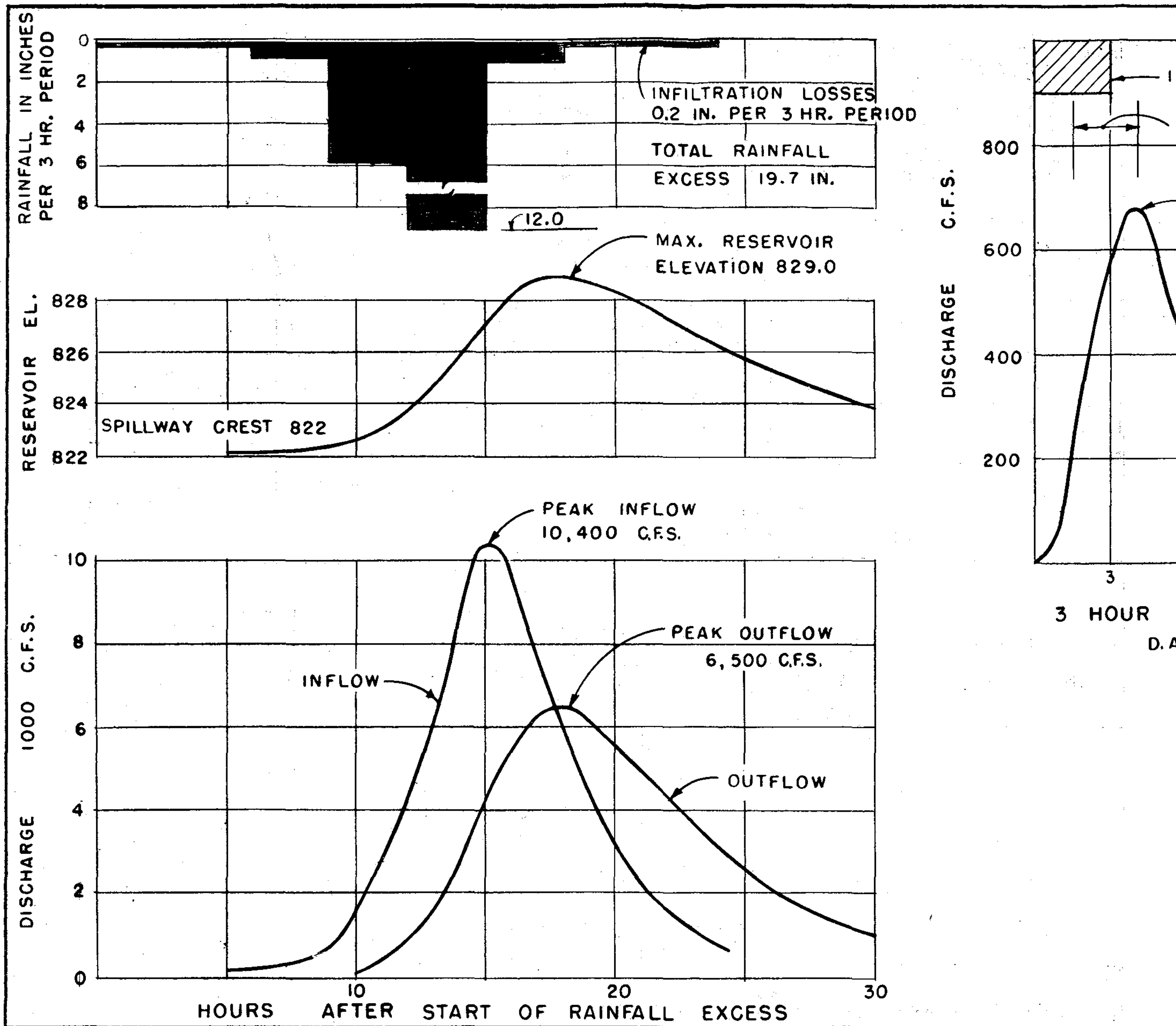
WATER RESOURCES DEVELOPMENT PLAN
CONNECTICUT RIVER BASIN

BEAVER BROOK LAKE

AREA-CAPACITY CURVES

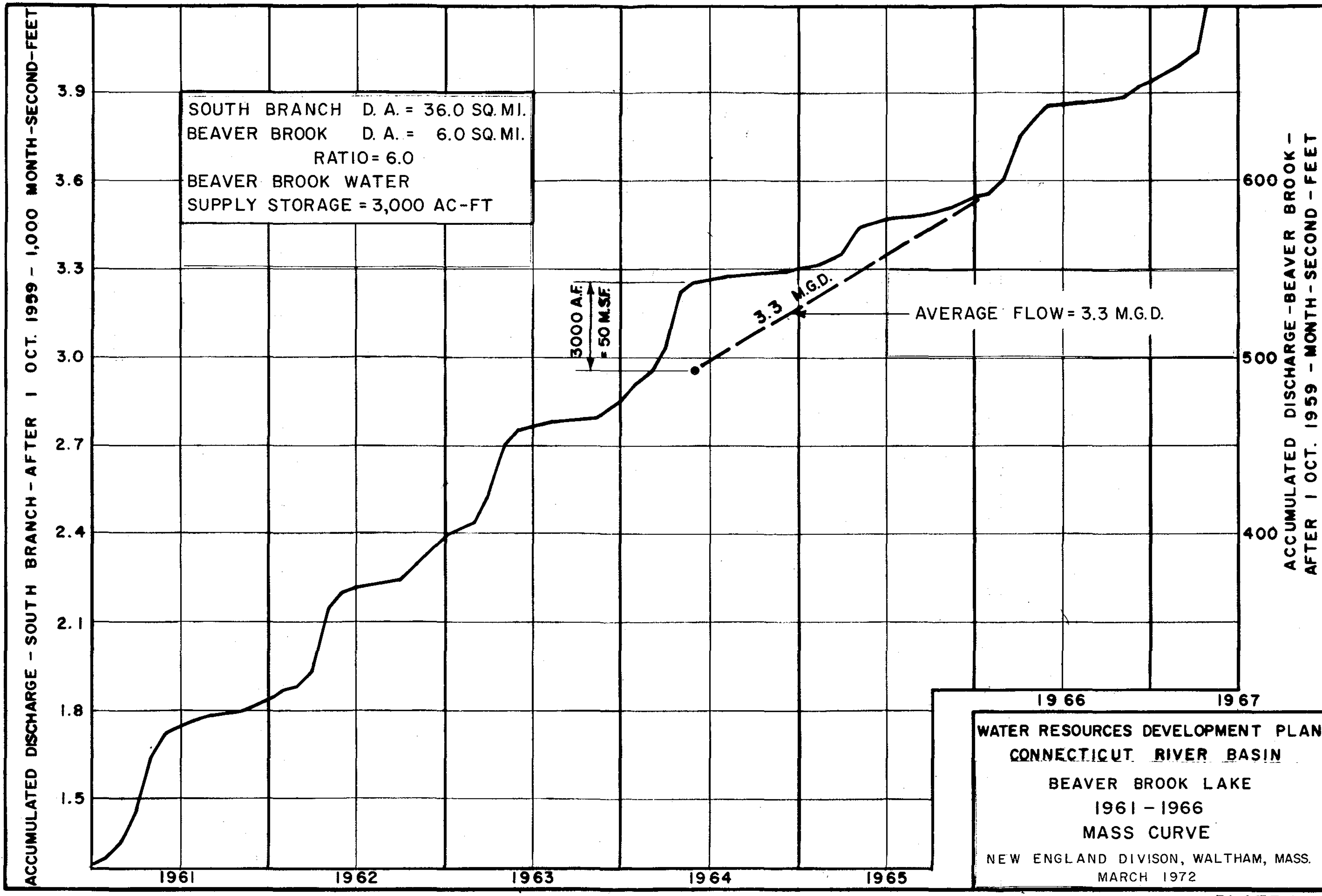
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 1-9



WATER RESOURCES DEVELOPMENT PLAN
CONNECTICUT RIVER BASIN
BEAVER BROOK
SPILLWAY DESIGN FLOOD
100 FT. SPILLWAY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 1-10



WATER RESOURCES DEVELOPMENT PLAN

CONNECTICUT RIVER BASIN

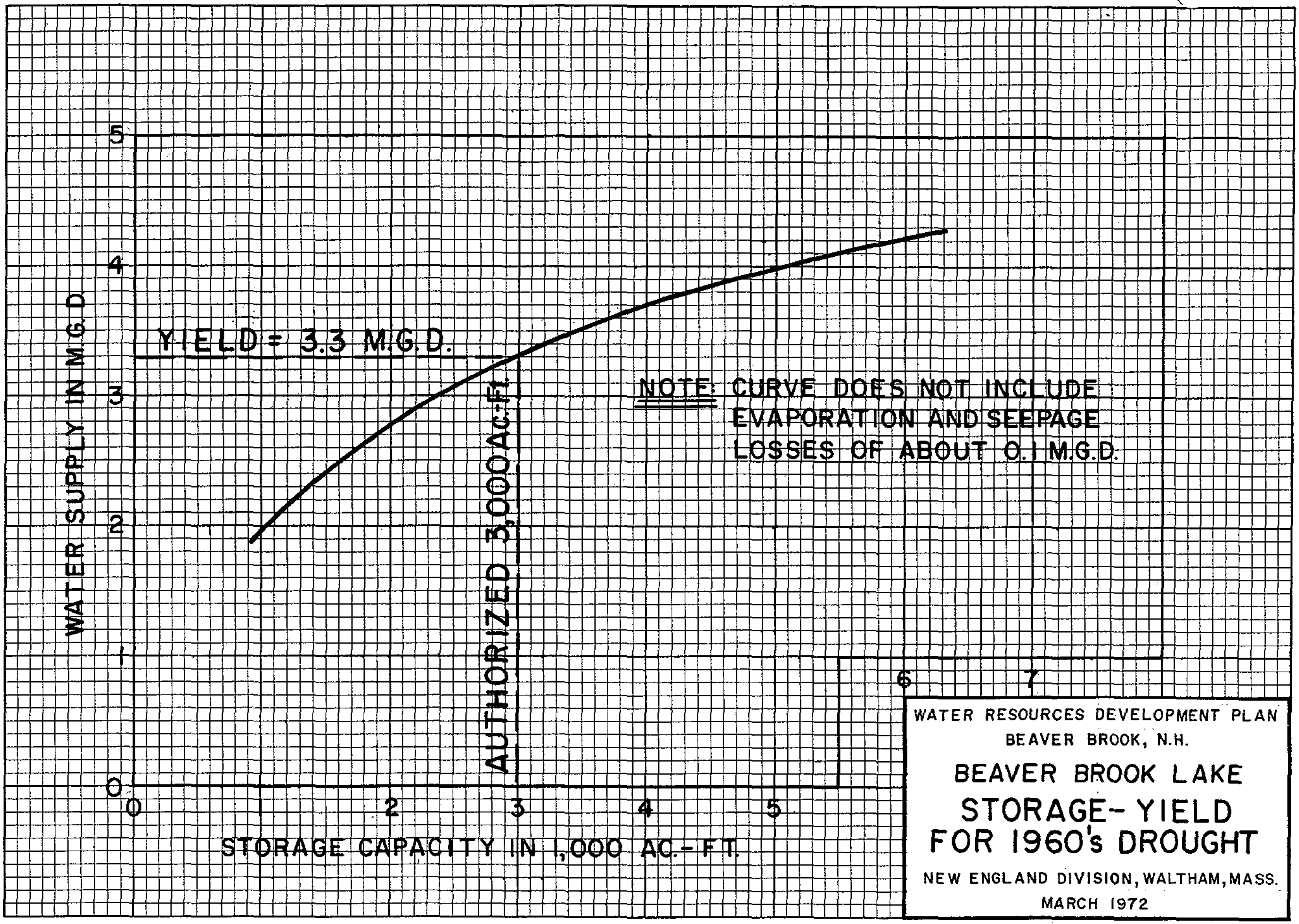
BEAVER BROOK LAKE

1961 - 1966

MASS CURVE

NEW ENGLAND DIVISON, WALTHAM, MASS.

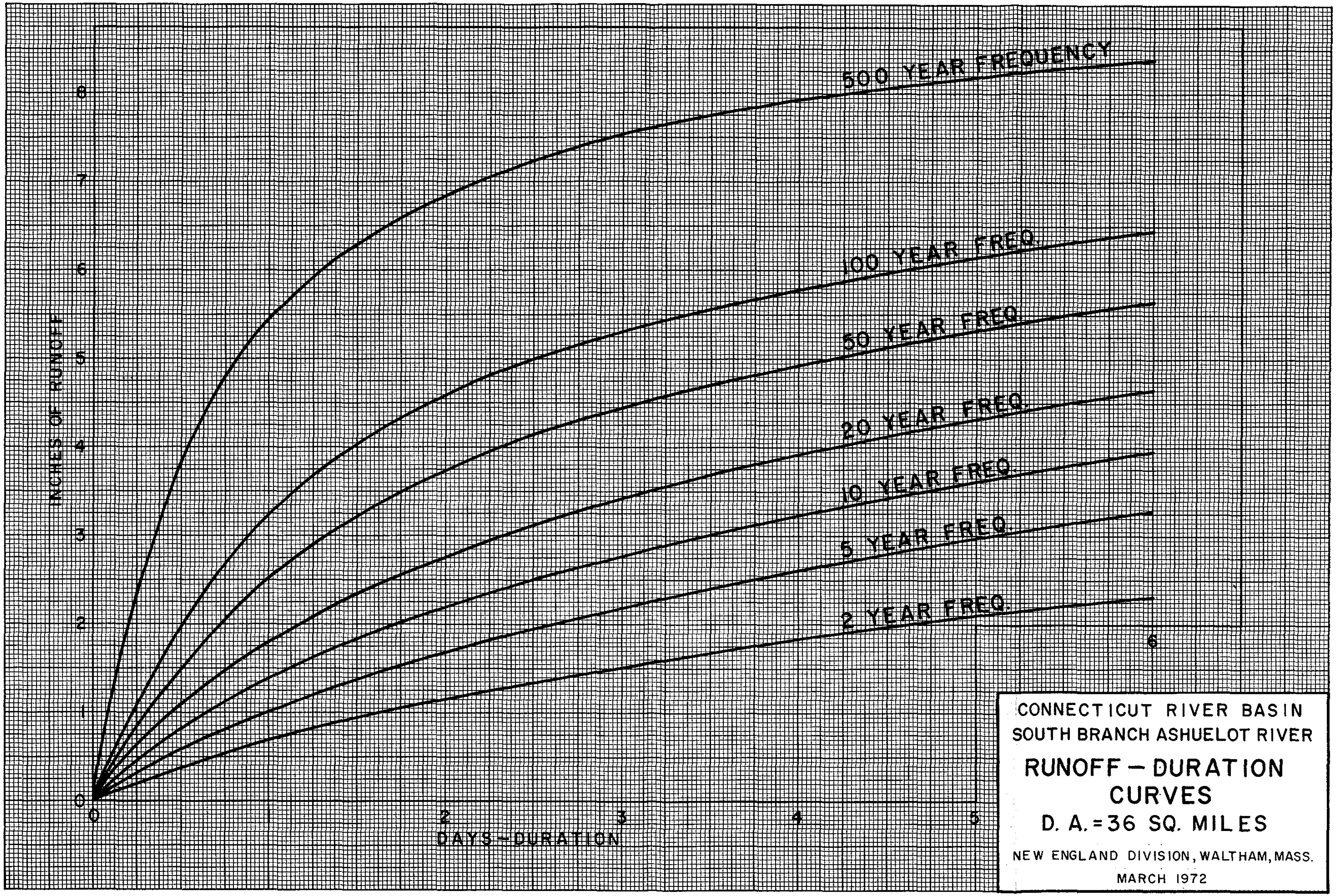
MARCH 1972



WATER RESOURCES DEVELOPMENT PLAN
BEAVER BROOK, N.H.

BEAVER BROOK LAKE
STORAGE-YIELD FOR 1960's DROUGHT

NEW ENGLAND DIVISION, WALTHAM, MASS.
MARCH 1972

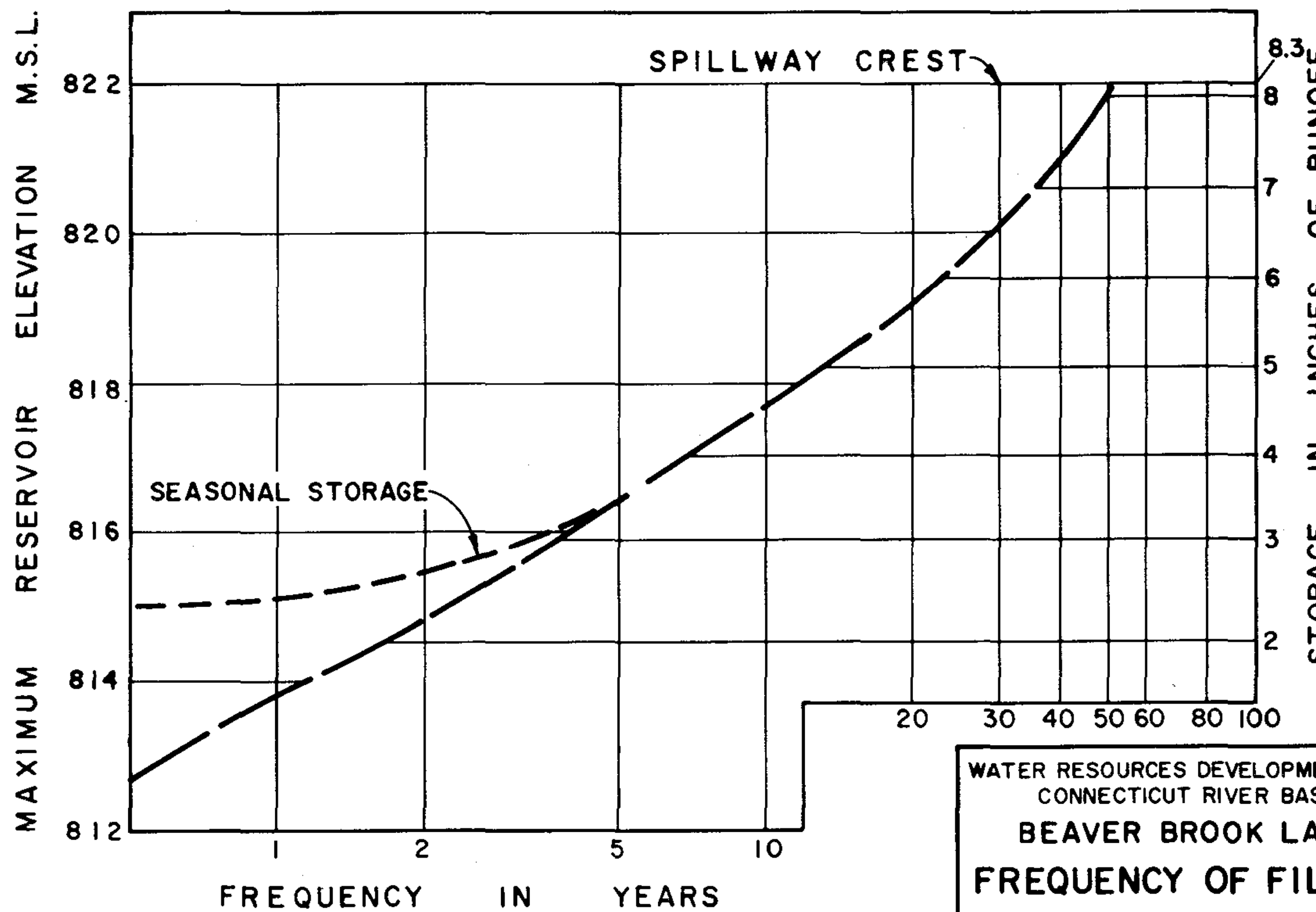


CONNECTICUT RIVER BASIN
SOUTH BRANCH ASHUELOT RIVER

RUNOFF — DURATION CURVES

D. A. = 36 SQ. MILES

NEW ENGLAND DIVISION, WALTHAM, MASS.
MARCH 1972

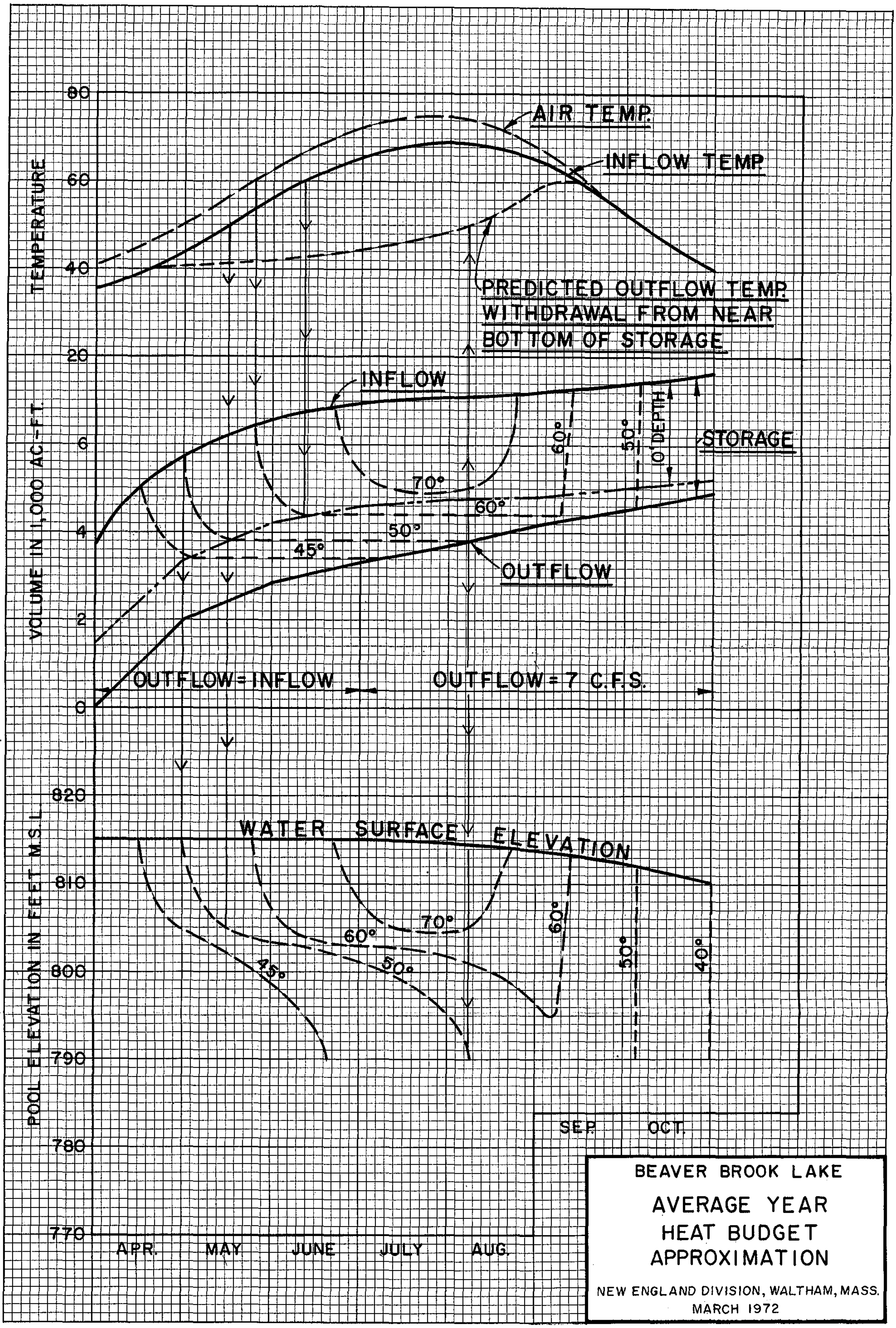


WATER RESOURCES DEVELOPMENT PLAN
CONNECTICUT RIVER BASIN

BEAVER BROOK LAKE

FREQUENCY OF FILLING

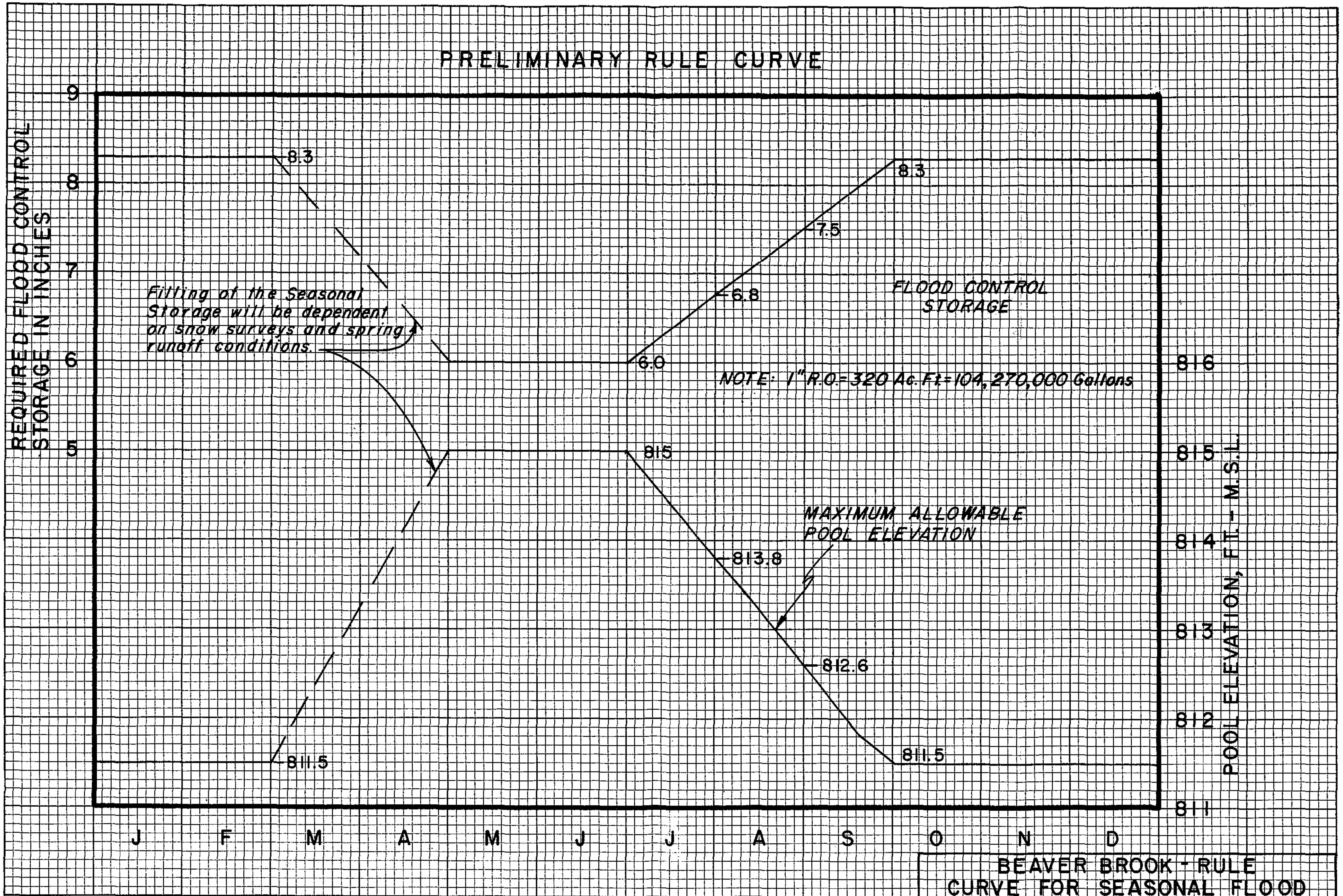
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.



BEAVER BROOK LAKE

AVERAGE YEAR
HEAT BUDGET
APPROXIMATION

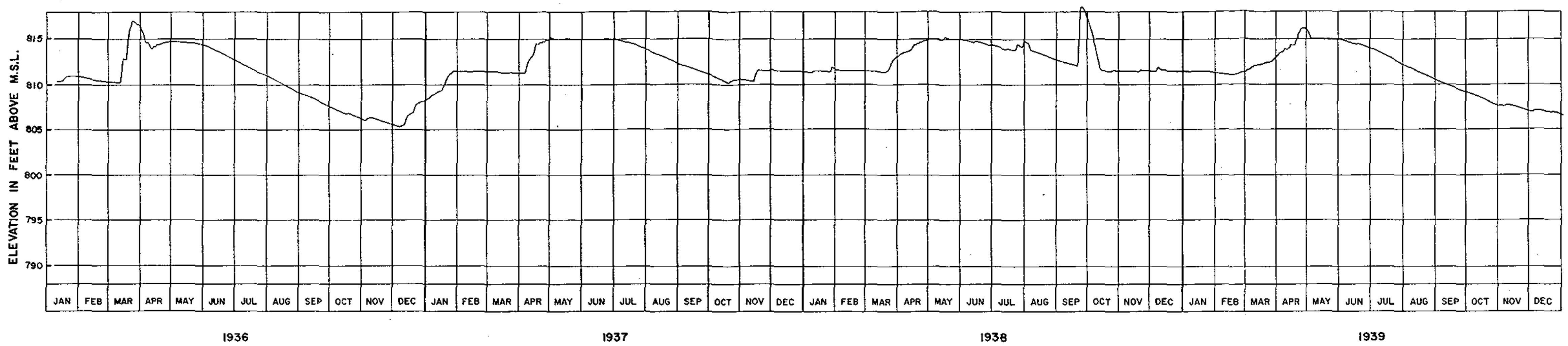
NEW ENGLAND DIVISION, WALTHAM, MASS.
MARCH 1972

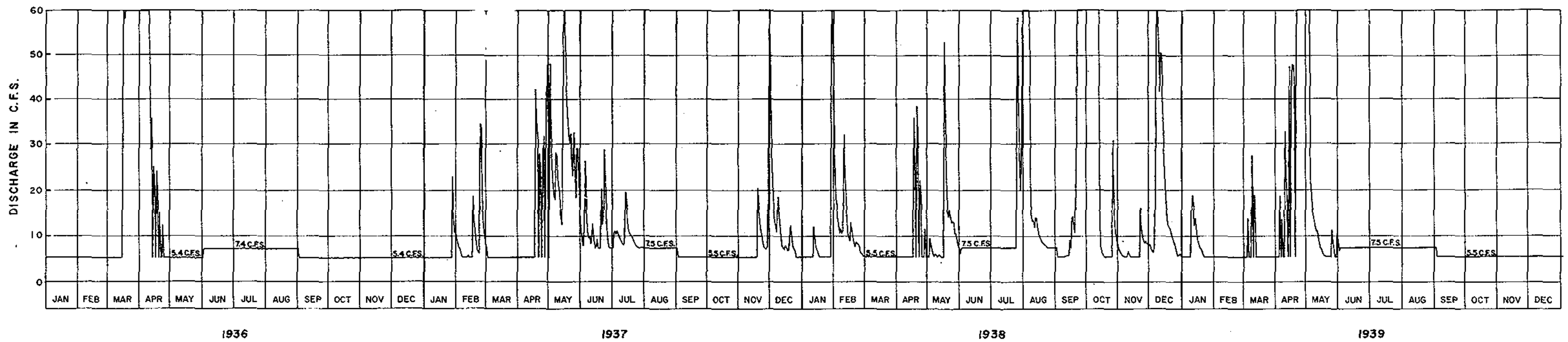


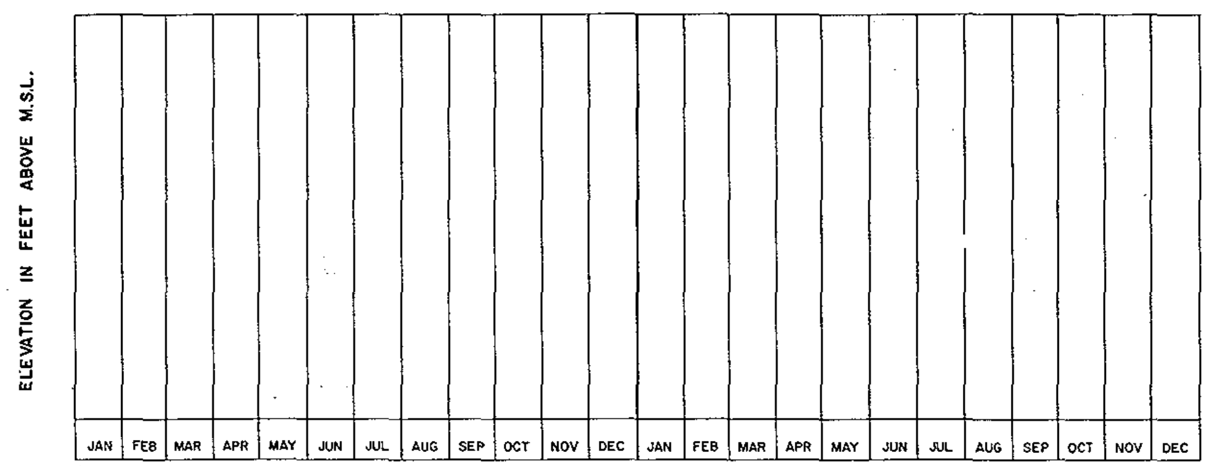
BEAVER BROOK - RULE CURVE FOR SEASONAL FLOOD CONTROL STORAGE

PLATE I-16

CORPS OF ENGINEERS　　　　U. S. ARMY







NOTES:

1. WATER SUPPLY REQUIREMENTS JUNE-AUGUST 6.5 c.f.s. SEPTEMBER-MAY 4.5 c.f.s. (YIELD = 5.0 c.f.s.)
2. MINIMUM DOWNSTREAM RELEASE WILL BE NORMALLY ONE c.f.s. OR 1.547 M.G.D. NO RELEASE WILL BE MADE IF POOL ELEVATION IS BELOW 811.5 M.S.L. ON FIRST OF *MAY OR UNTIL RULE CURVE IS REACHED.*
3. DISCHARGE UP TO 60 c.f.s. WILL BE RELEASED WHENEVER POOL IS 100 ACRE-FEET ABOVE RULE CURVE.
4. FLOWS BASED ON DRAINAGE AREA PROPORTION WITH OTTER BROOK GAGING STATION RECORDS.
5. REFER TO RULE CURVE ON PLATE 1-16.

SAFETY PAYS

GRAPHIC SCALES

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

SUBMITTED: CHIEF, SECTION

APPROVAL RECOMMENDED: CHIEF, TECH. ENG. BRANCH

REVIEWED: PROJECT ENGINEER

APPROVAL RECOMMENDED: CHIEF BRANCH

BEAVER BROOK LAKE
POOL STAGES AND OUTFLOWS
1936-1939 (WET PERIOD)

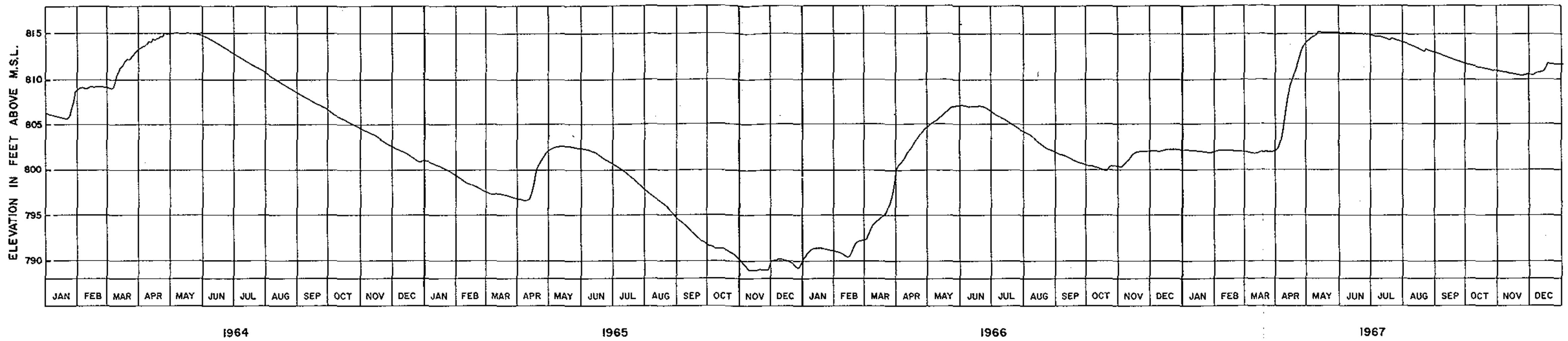
APPROVED CHIEF, ENGINEERING DIVISION　DATE

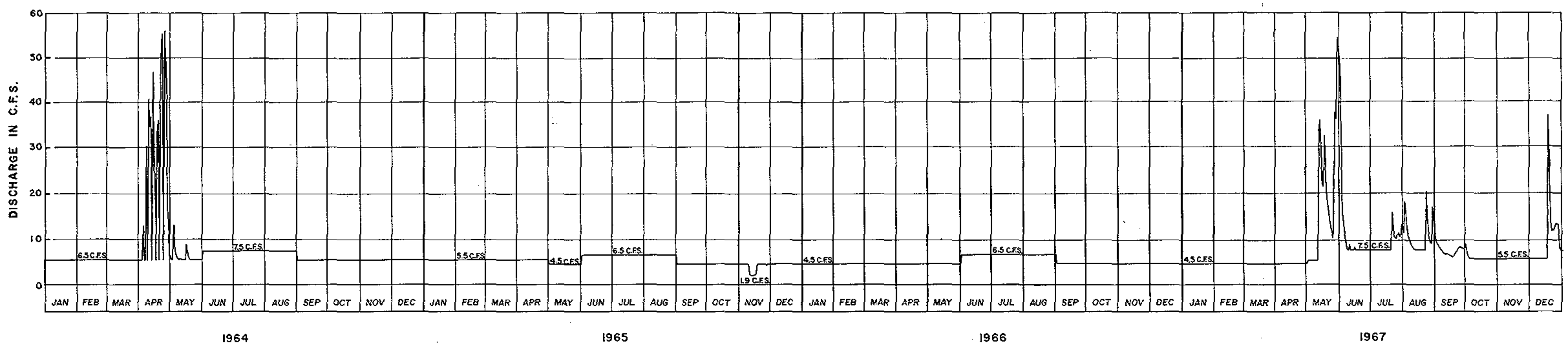
SCALE | SPEC. NO.

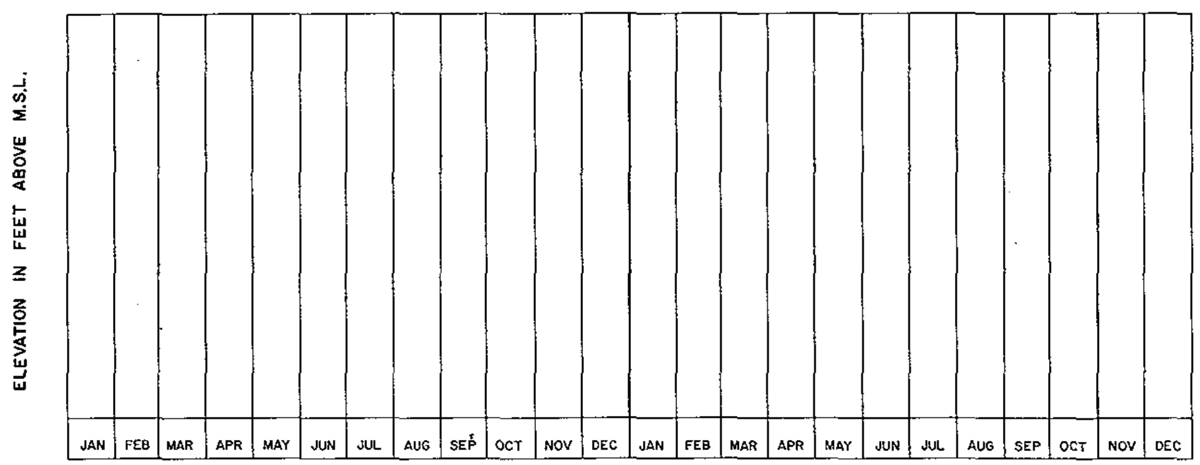
DRAWING NUMBER

SHEET 1

CORPS OF ENGINEERS   U. S. ARMY







GRAPHIC SCALES

REVISION	DATE	DESCRIPTION	BY

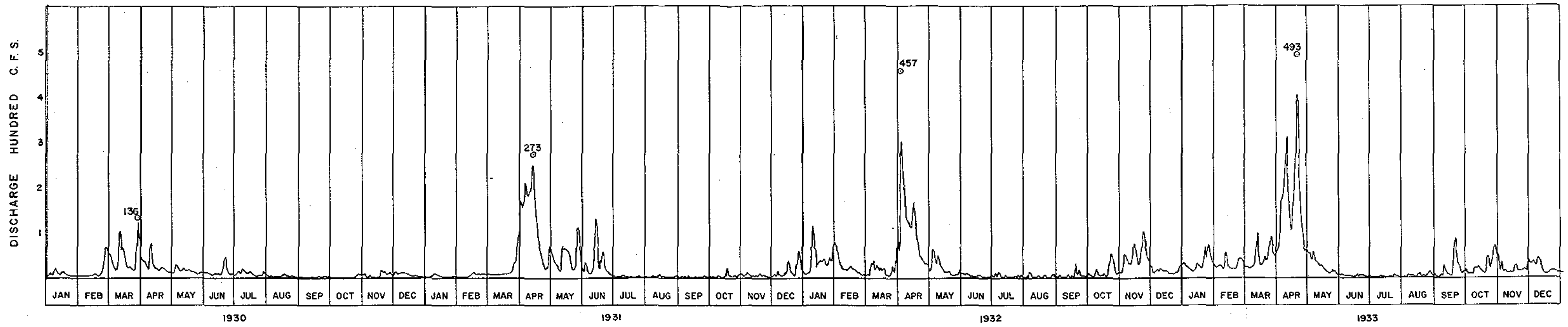
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

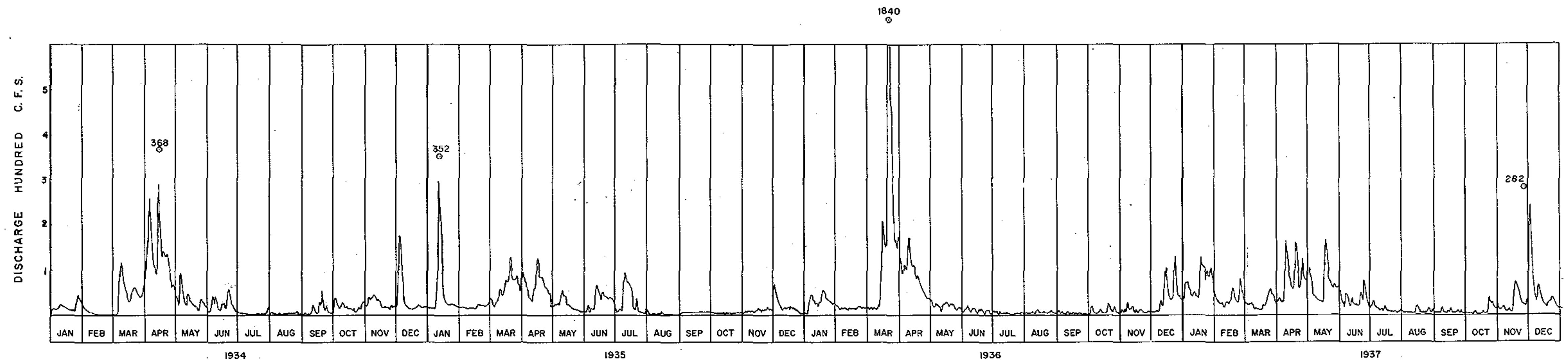
BEAVER BROOK LAKE
POOL STAGES AND OUTFLOWS
1964-1967 (DRY PERIOD)

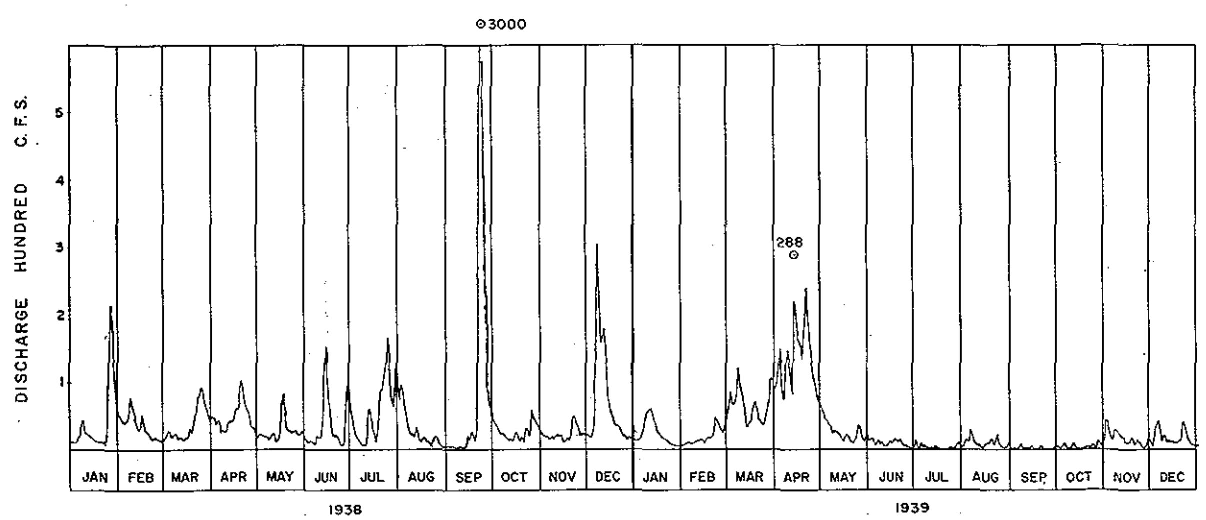
SHEET 3

PLATE I-19

CORPS OF ENGINEERS U. S. ARMY







NOTES:

1. THESE HYDROGRAPHS ARE DAILY AVERAGE FLOW RECORDS DETERMINED FROM A U.S. GEOLOGICAL SURVEY GAGING STATION ON PRIEST BROOK NEAR WINCH NDON, MASS. FROM A TOTAL DRAINAGE AREA OF 19.4 SQUARE MILES. THE TRIBUTARY DRAINAGE AREA OF BEAVER BROOK LAKE IS 6.0 SQUARE MILES.
SOME INSTANTANEOUS PEAK DISCHARGES ARE SHOWN BY ⊙.

2. THE DATA CONTAINED HEREON ARE NOT INTENDED AS REPRESENTATIONS OR WARRANTIES BUT ARE FURNISHED AS INFORMATION ONLY. IT IS EXPRESSLY UNDERSTOOD THAT THE GOVERNMENT WILL NOT BE RESPONSIBLE FOR ANY DEDUCTION, INTERPRETATION OR CONCLUSION THEREFROM MADE BY ANY BIDDER OR CONTRACTOR.

GRAPHIC SCALES

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

SUBMITTED: CHIEF, SECTION

APPROVAL RECOMMENDED: CHIEF, TECH. ENG. BRANCH

REVIEWED: PROJECT ENGINEER

APPROVAL RECOMMENDED: CHIEF BRANCH

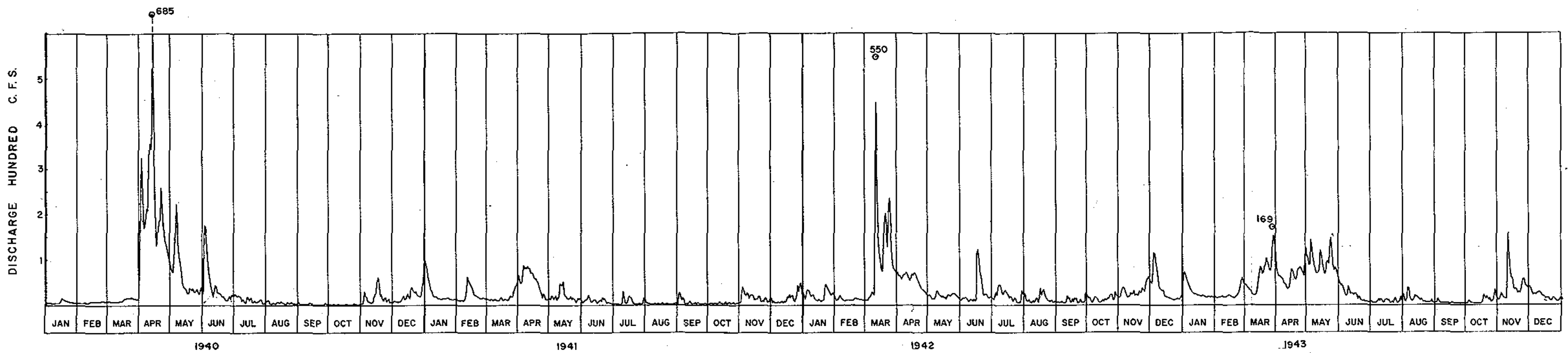
WATER RESOURCES DEVELOPMENT PLAN
BEAVER BROOK LAKE
HYDROGRAPHS NO. 1
1930 ~ 1939

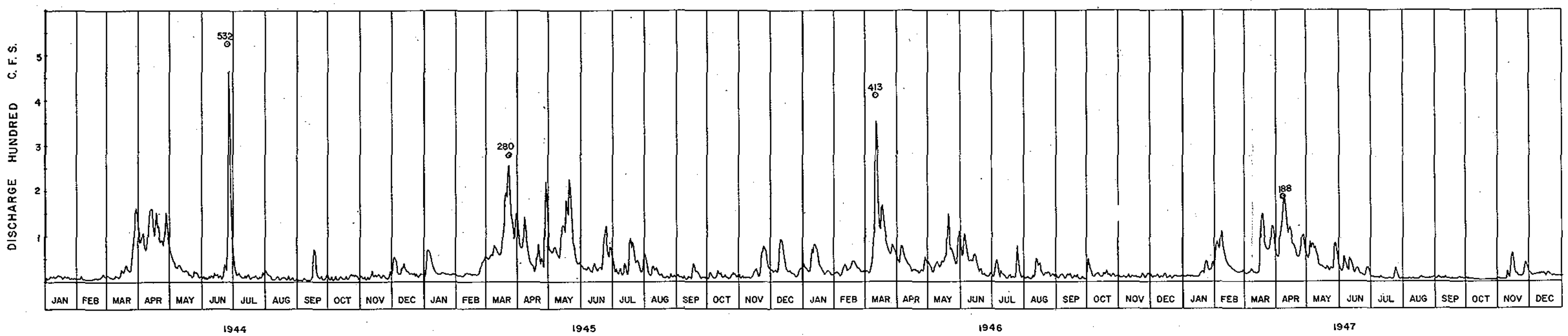
PRIEST BROOK WINCHENDON, MASSACHUSETS

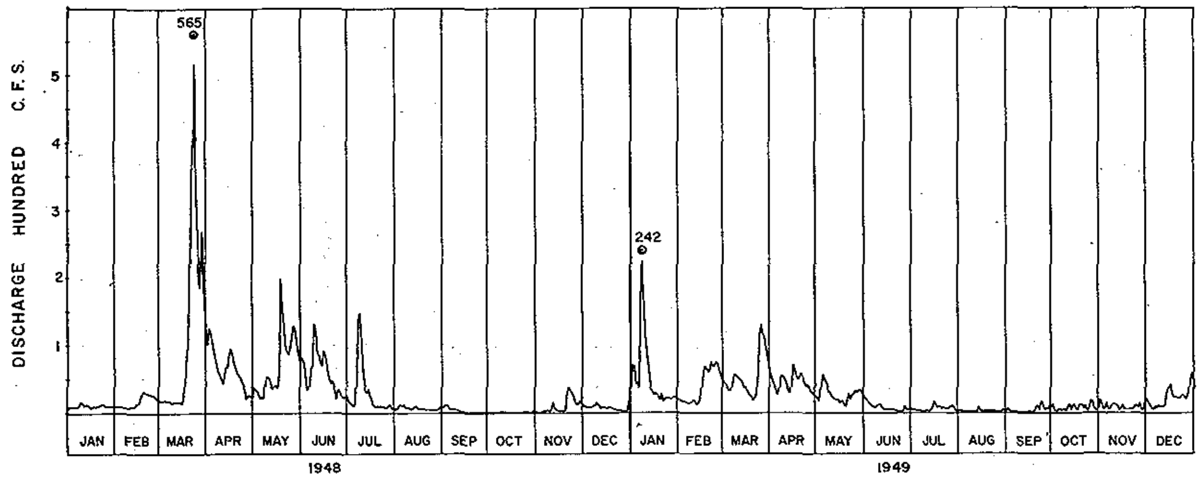
APPROVED CHIEF, ENGINEERING DIVISION DATE

SCALE | SPEC. NO.
DRAWING NUMBER

CORPS OF ENGINEERS A B C D E F G H U. S. ARMY







NOTE
FOR NOTES REFER TO HYDROGRAPHS NO. 1

GRAPHIC SCALES

SAFETY PAYS

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

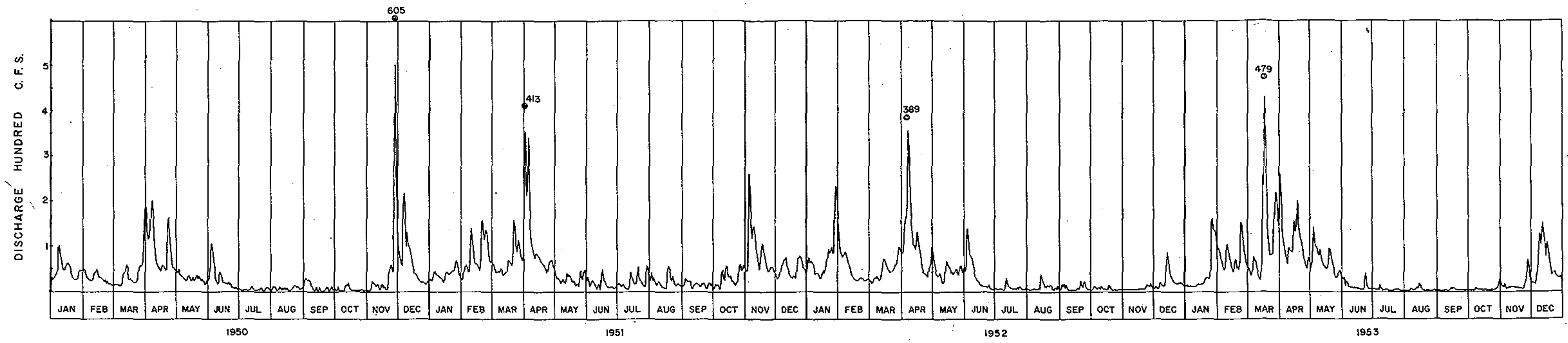
WATER RESOURCES DEVELOPMENT PLAN
BEAVER BROOK LAKE
HYDROGRAPHS NO. 2
1940 - 1949

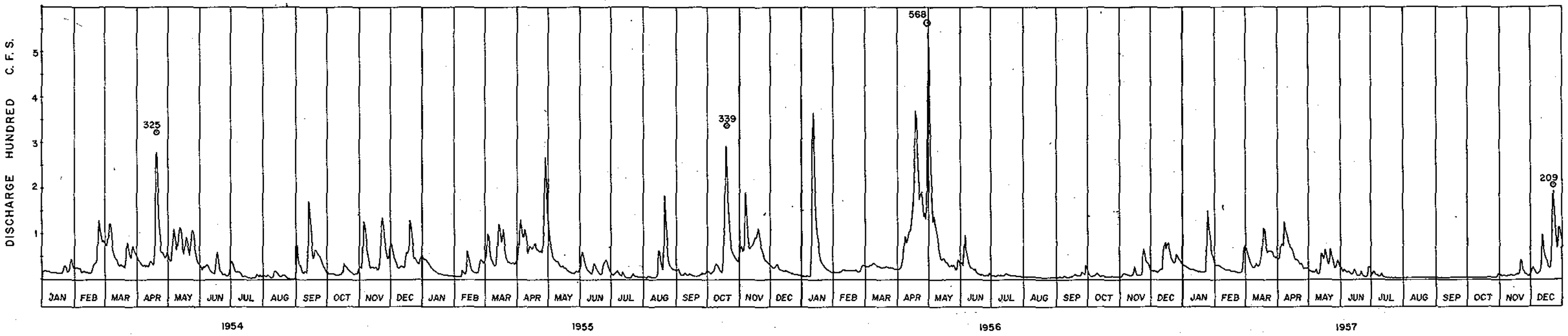
PRIEST BROOK WINCHENDON, MASSACHUSETS

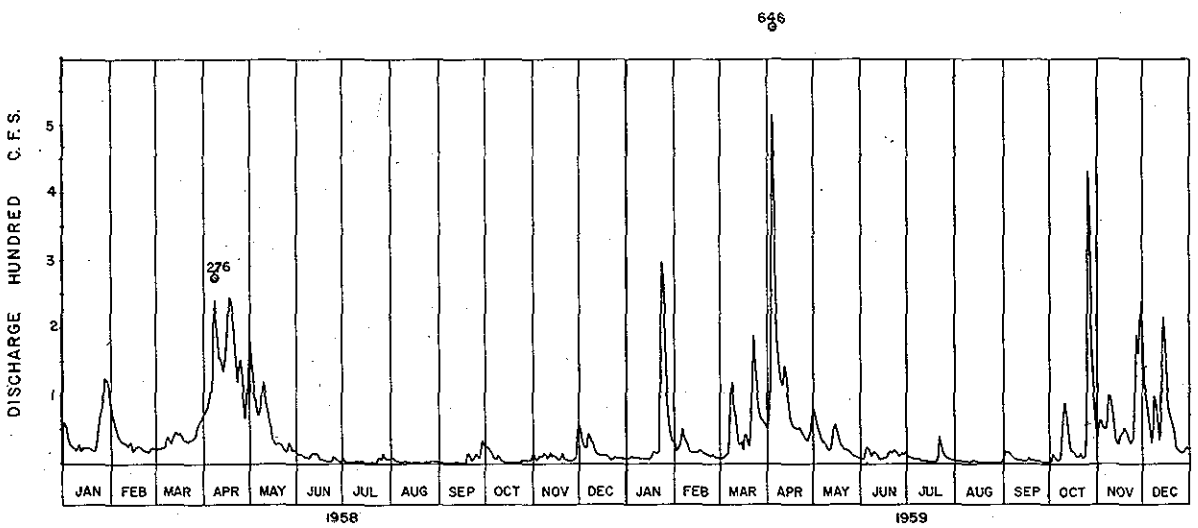
DES. BY | DR. BY | CK. BY
SUBMITTED:
CHIEF, SECTION
APPROVAL RECOMMENDED:
CHIEF, TECH. ENG. BRANCH
REVIEWED:
PROJECT ENGINEER
APPROVAL RECOMMENDED:
CHIEF BRANCH
APPROVED DATE
CHIEF, ENGINEERING DIVISION
SCALE SPEC. NO.
DRAWING NUMBER

PLATE 1-21

CORPS OF ENGINEERS U. S. ARMY







NOTE
FOR NOTES REFER TO HYDROGRAPHS NO. 1

GRAPHIC SCALES

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

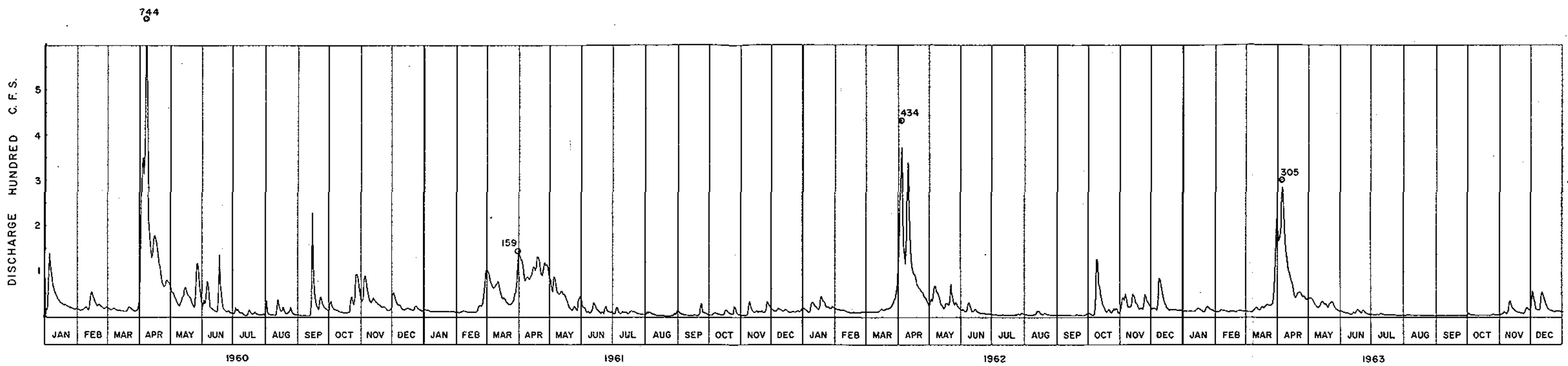
WATER RESOURCES DEVELOPMENT PLAN
BEAVER BROOK LAKE
HYDROGRAPHS NO. 3
1950 - 1959

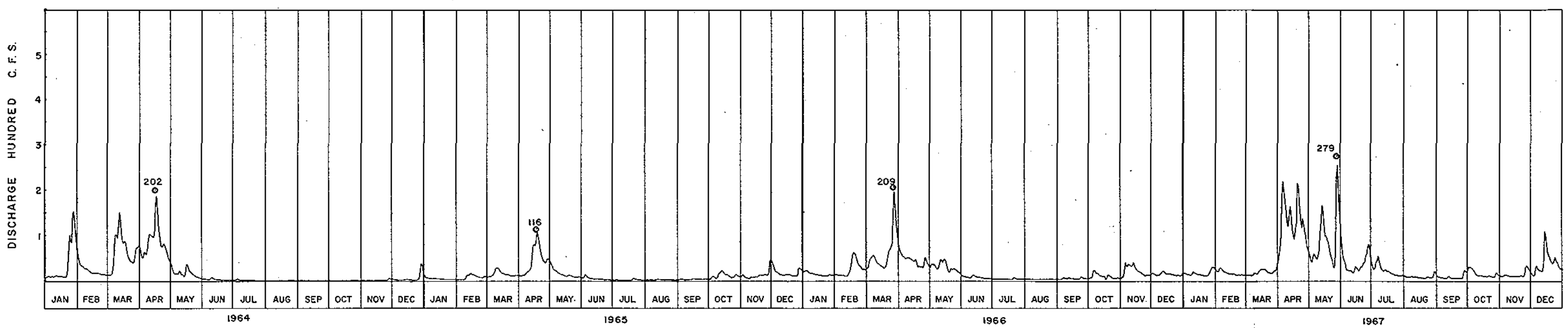
PRIEST BROOK WINCHENDON, MASSACHUSETS

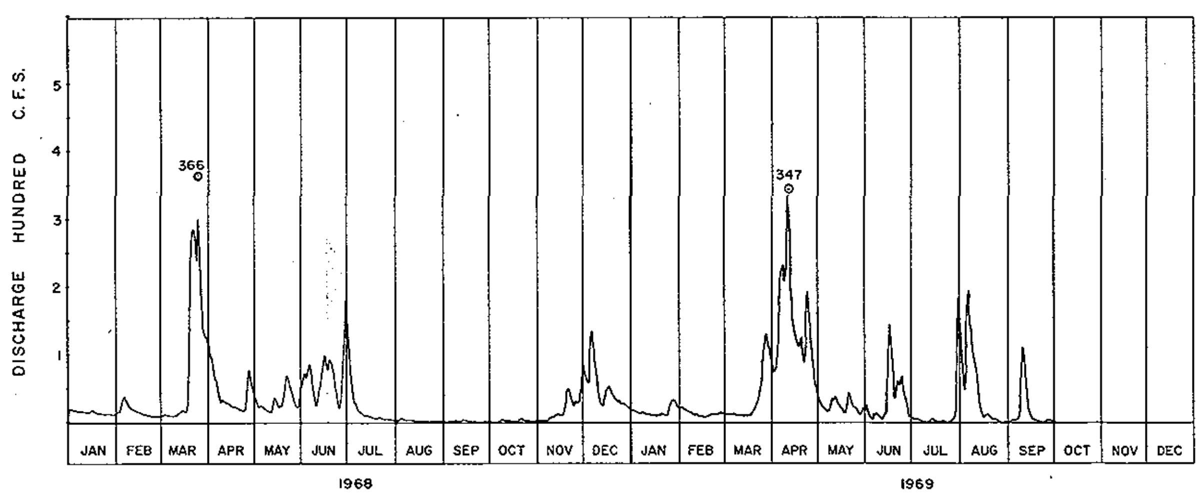
DES. BY | DR. BY | CK. BY
SUBMITTED
CHIEF, SECTION
APPROVAL RECOMMENDED
CHIEF, TECH. ENG. BRANCH
REVIEWED
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF, BRANCH
APPROVED
DATE
CHIEF, ENGINEERING DIVISION
SCALE
SPEC. NO.
DRAWING NUMBER

PLATE I-22

CORPS OF ENGINEERS A B C D E F G H U. S. ARMY







NOTE
FOR NOTES REFER TO HYDROGRAPHS NO. I

GRAPHIC SCALES

REVISION DATE DESCRIPTION BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

WATER RESOURCES DEVELOPMENT PLAN
BEAVER BROOK LAKE
HYDROGRAPHS NO. 4
1960 - 1969

PRIEST BROOK WINCHENDON, MASSACHUSETS

PLATE I-23